भारतीय मानक

Indian Standard

IS 732 : 2019

विद्युतियी वायरिंग अधिष्ठापनों के लिए रीति संहिता

(चौथा पुनरीक्षण)

Code of Practice for Electrical Wiring Installations

(Fourth Revision)

ICS 91.140.50

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली–110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
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FOREWORD

This Indian Standard (Fourth Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Electrical Installation Sectional Committee had been approved by Electrotechnical Division Council.

This standard was first published in 1958 to guide and govern installation of electrical wiring in buildings with particular reference to safety and good engineering practice.

The second revision of this standard was brought out in 1982 in 3 parts. Soon after the publication of the second revision, work on the preparation of National Electric Code (NEC) began. NEC was published in 1985. NEC, besides drawing assistance from IS 732, further elaborates the stipulations on wiring practice with reference to specific occupancies.

Soon after the publication, major revision of IS 732 was carried out in order to align with the modified pattern of power consumption and advance technology in installation design. There was also a strong need to align the Code with international level, namely at the level of IEC/TC 64 'Electrical Installation of Building'. The third revision was published in 1989.

Since publication of IS 732: 1989, lot of changes have taken place in Indian Electrical scenario. Due to increase of population and rapid urbanization over last few decades there has been significant increase in residential, commercial and other buildings in all major cities in India. This has led to a significant rise in the installation of electrical wiring and electrical services in all types of buildings in urban, semi-urban and rural areas.

NEC 2011 has since been published taking into account many of the changes mentioned above. Central Electricity Authority has also brought out regulations for "Measures relating to safety and electric supply".

The work of fourth revision of IS 732 started almost simultaneously with preparation of NEC 2011. Initially, Committee was working to align this standard completely with IEC Standard and planning to make this standard as IS/IEC 60364 series 'Low-voltage Electrical Installation'. However, further study revealed that many significant changes are required to ensure that this standard is in line with NEC 2011, CEA Regulations, 2010 and present Indian environment and power supply conditions.

This version of IS 732 is largely based on the following standards:

IEC 60364-1 : 2005	Low-voltage electrical installations — Part 1: Fundamental principles, assessment of general characteristics, definitions
IEC 60364-4-41 : 2005	Low-voltage electrical installations — Part 4-41: Protection for safety — Protection against electric shock
IEC 60364-4-42 : 2010	Low-voltage electrical installations — Part 4-42: Protection for safety — Protection against thermal effects
IEC 60364-4-43 : 2008	Low-voltage electrical installations — Part 4-43: Protection for safety — Protection against over current
IEC 60364-4-44 : 2007	Low-voltage electrical installations — Part 4-44: Protection for safety — Voltage disturbance and electromagnetic disturbance
IEC 60364-5-51 : 2005	Electric installations of buildings — Part 5-51: Selection and erection of electrical equipment — Common rules
IEC 60364-5-52 : 2009	Electric installations of buildings — Part 5-52: Selection and erection of electrical equipment — Wiring systems
IEC 60364-5-53 : 2015	Electric installations of buildings — Part 5-53: Selection and erection of electrical equipment — Isolation switching and control

IEC 60364-5-54 : 2011	Electric installations of buildings — Part 5-54: Selection and erection of electrical equipment — Earthing arrangements and protective conductors
IEC 60364-5-55 : 2016	Electric installations of buildings — Part 5-55: Selection and erection of electrical equipment — Other equipment
IEC 60364-5-56 : 2009	Electric installations of buildings — Part 5-56: Selection and erection of electrical equipment — Safety services
IEC 60364-6 : 2016	Low voltage electrical installations — Part 6: Verification

Necessary changes have been made to ensure that the above mentioned points are taken care of. Whenever necessary, provision of this code shall be read in conjunction with other codes such as those on earthing, lightning protection and the National Electrical Code.

The major deviations from the IEC standards are listed below. These differences are mainly because the revision takes into account the National Electric Code and CEA notification dated 20th September 2010 for 'Measures relating to Safety and Electric supply':

a) All country specific comments and notes for special applications mentioned in IEC 60364 have not been incorporated in this standard.

b) CEA Rule 42 – Earth leakage protection: To align with CEA Rule 42 and the National Electrical Code, the provisions given in IEC standards have been modified to ensure uniform application of RCD for protection in this standard.

c) CEA Rule 41 % Connection with Earth: To align with CEA Rule 41 and National Electric Code, earthing systems have been modified. For example as per CEA and National Electric Code 2011, for 415 V systems, double earthing is mandatory. Also a section on earthing will follow in the National Electric Code and IS 3043.

d) IEC 60364 -5- 52 wiring Installation: Minimum nominal cross-sectional area of Conductors has been changed as per National Electric Code in this standard.

The provisions of IEC 60364-7 'Requirements for special installations or locations' is not included in the requirements of IS 732 as it shall be incorporated in National Electric Code during its revision.

Indian Standard

CODE OF PRACTICE FOR ELECTRICAL WIRING INSTALLATIONS

(Fourth Revision)

1 SCOPE

This Code gives the rules for the design, erection, and verification of electrical installations. The rules are intended to provide for the safety of persons, livestock and property against dangers and damage which may arise in the reasonable use of electrical installations and to provide for the proper functioning of those installations.

1.1 General

This standard applies to the design, erection and verification of electrical installations such as those of:

a) residential premises,
b) commercial premises,
c) public premises,
d) industrial premises,
e) agricultural and horticultural premises,
f) photovoltaic systems, and
g) low-voltage generating sets.

NOTE — "premises" covers the land and all facilities including buildings belonging to it.

1.2 This standard include requirements for:

a) circuits supplied at normal voltage upto and including 1 000V a.c. or 1 500V d.c. For a.c., the preferred frequencies which are taken into account in this standard are 50 Hz, 60 Hz and 400 Hz.The use of other frequencies for special purposes is not excluded.
b) circuits, other than the internal wiring of equipment, operating at voltage exceeding 1 000 V a.c., for example discharge lighting, electro static precipitator, X-ray and scanning apparatus, high voltage electrode boilers.
c) wiring systems and cables not specifically covered by the standards for appliances, namely product standards.
d) all consumer installations external to buildings.
e) fixed wiring for information and communication technology, signalling, control and the like (excluding internal wiring of equipment).
f) any extension, namely, additions and alteration to installations and also parts of the existing installation affected by an addition or alteration.

1.2.1 This standard applies to items of electrical equipment only, so far as, its selection and application in the building electrical installation are concerned. The rules in this standard do not deal with the requirements for the factory-built construction of electrical equipment, namely, type tested (TT) and partially type tested (PTT), Switchgear and Controlgear Assemblies, Distribution Boards, Fuse Distribution Boards, Circuit Breaker Distribution Boards, Bus-bar Trunking Systems (bus-ways), electric supply track systems for luminaries, power track system intended for wall and ceiling mounting, boxes and enclosures for electrical accessories for house-hold and similar fixed electrical installations, electricity control units known as Consumer Units or Consumer Control Units. The factory-built assemblies of these electrical equipment are required to comply with IS 8623 (all parts), IS 14772, BSEN 60439-1, BSEN 60439-2, BSEN 60439-3. BSEN 60439-4, BSEN 60570, BSEN 60570-2-1, BSEN 60670-1, BSEN 60670-22, IEC 60670-21, BSEN 61534-21 and other relevant Indian Standards/IEC Standards.

1.2.2 This standard does not apply to the following electrical installations:

a) construction sites, exhibitions, shows, fairgrounds and other installations for temporary purposes including professional stage and broadcast applications;
b) marinas;
c) external lighting and similar installations;
d) mobile or transportable units;
e) highway equipment and street furniture;
f) medical locations;
g) operating and maintenance gangways;
h) pre-fabricated building;
j) systems for the distribution of electricity to the public by Electricity Distribution Companies governed by the Central Electricity Authority Regulations made under the *Electricity Act,* 2003;
k) power generation and transmission for such distribution system in (a);
m) railway traction equipment, rolling stock and signalling equipment;
n) electrical equipment of motor vehicles, except those to which the requirements of the regulation

concerning mobile units are applicable;

p) electrical equipment on board ships;
q) electrical equipment of mobile and fixed off-shore installations;
r) electrical equipment in aircraft;
s) those aspects of mines and quarries which are specially covered by statutory Regulation under *Mines Act,* 1952 (35 of 1952);
t) radio interference suppression equipment, except so far as, it affects safety of the electrical installation;
u) external lighting protection systems (LPS) for buildings and structures covered under IS/IEC 62305;
v) safety machinery and electric equipment of machinery covered under *Factory Act*, 1948 and other Special Publications of BIS;
w) those aspects of lift installations which are covered under relevant parts of statutory Rules made under *Helps Act* framed by various states in India and also covered by the various Indian Standards on Lifts and Escalators formulated by BIS;
x) electric fences covered by relevant Indian Standard relating to Electrical safety in consumer's appliances; and
y) public street-lighting installation which are part of distribution system by Public utility under the *Electricity Act,* 2003.

1.3 Installation of Premises Subject to Licensing

For installation of premises over which a licensing or other authority exercises a statutory control, the requirements of that authority shall be as ascertained and complied with in the design and execution of the installation.

1.3.1 The relationship with the Central Electricity Authority (Measure Relating to Safety and Electric Supply) Regulations 2010, and Regulations made by appropriate Electricity Regulatory Commission under *Electrically Act*, 2003 is as given below:

The legal status of this standard, including other Codes of Practice Standards of the Bureau of Indian Standard or National Electrical Code, is explained in sub-regulation (2) of Regulation 12 of the Central Electricity Authority (Measure Relating to Safety and Electric Supply) Regulations, 2010. Hence, these Rules may be used to satisfy any statutory approving authority under the *Electricity Act*, 2003 or in any Court of Law in evidence to claim compliance with a statutory requirement.

The rules in this Code, however, are intended to supplement the Statutory Regulations made by the appropriate Electricity Regulatory Commission and in the event of any inconsistency; the provisions of those regulations made by the appropriate Electricity Regulatory Commission shall prevail. The Electricity Regulatory Commissions in the Supply Code and Distribution Code made by them generally include a deeming provision that the statutory requirements in Supply Code and Distribution Code are duly observed by users and consumers of electricity, if the electrical installation owned by them are constructed, installed, protected, inspected, tested, operated, worked and maintained according to this Indian Standard besides, complying with the provisions of sub regulation (1), (3) and (4) of the Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations, 2010 and all other applicable statutory regulations made under the *Electricity Act*, 2003.

2 REFERENCES

The standards given below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of these standards.

IS No./ International Standards	*Title*
1293 : 2005	Plugs and socket — outlets of rated voltage up to and including 250 volts and rated current up to 16 amperes
1885	Electrotechnical vocabulary:
(Part 37) : 1993	Part 37 Tariffs for Electricity (*first revision*)
(Part 70) : 1993/ IEC 60050 (604) : 1987	Generation, transmission and distribution of electricity — Operation
8130 : 2013	Conductors for insulated electric cables and flexible cords (*second revision*)
8623 (Part 1) : 1993/ IEC 60439-1(1985)	Low-voltage switchgear and and controlgear assemblies: Part 1 Type-tested and partially type-tested assemblies
8623 (Part 2) : 1993/ IEC 60439-2 (1987)	Low-voltage switchgear and controlgear assemblies: Part 2 Particular requirements for busbar trunking systems (busways)
9000 (Part 11) : 1983	Basic environmental testing procedures for electronic and electrical items: Part 11 Salt mist test
9537 (All Parts)	Conduits for electrical installations — Specification
10322 (All Parts)	Luminaires

IS No./ International Standards	*Title*
11731 (All Parts)	Methods of test for determination of the flammability of solid electrical insulating materials when exposed to an igniting source
12032 (All Parts)	Graphical symbols for use on equipment
12360 : 1988	Voltage bands for electrical installations including preferred voltages and frequency
13234 (Part 0) : 2016	Short-circuit currents in three-phase a.c. systems: Part 0 Calculation of currents (*first revision*)
13252 (Part 1) : 2010/ IEC 60950-1 : 2005	Information technology equipment — Safety: Part 1 General requirements
13703	Low voltage fuses for voltages not exceeding 1 000 V ac or 1 500 V d.c.:
(Part 2/Sec 1) : 1993	Fuses for use by authorized persons, Section 1 Supplementary requirements
(Part 4) : 1993	Supplementary requirements for fuse-links for the protection of semiconductor devices
13736 (All Parts)	Classification of environmental conditions
14700	Electromagnetic compatibility (EMC):
(Part 4/Sec 2) : 2008	Testing and measurement techniques, Section 2 Electrostatic discharge immunity test
(Part 4/Sec 3) : 2008	Testing and measurement techniques, Section 3 Radiated, radio-frequency, electromagnetic field immunity test
(Part 4/Sec 4) : 2008	Testing and measurement techniques, Section 4 Electrical fast transient/burst immunity test
(Part 4/Sec 6) : 2016	Testing and measurement techniques, Section 6 Immunity to conducted disturbances, induced by radio-frequency fields
(Part 4/Sec 8) : 2008	Testing and measurement techniques, Section 8 Power frequency magnetic field immunity test
(Part 4/Sec 12) : 2008	Testing and measurement techniques, Section 12 Oscillatory waves immunity test
(Part 6/Sec 1) : 2008	Generic standards, Section 1: Immunity for residential, commercial and light-industrial environments
(Part 6/Sec 2) : 2008	Generic standards, Section 2 Immunity for industrial environments
(Part 6/Sec 3) : 2002	Generic standards, Section 3 Emission standard for residential, commercial and light-industrial environments
14772 : 2000	Enclosures for accessories for household and similar fixed electrical installations
14927 (All Parts)	Cable trunking and ducting systems for electrical installations
14930 (All Parts)	Conduit systems for electrical installations
15382 (Part 1) : 2014	Insulation co-ordination for equipment within low-voltage systems: Part 1 Principles, requirements and tests
15697	Capacitors for use in tubular fluorescent and other discharge lamp circuits:
(Part 1) : 2013	Safety requirements
(Part 2) : 2013	Performance requirements
16242	Uninterruptible power systems (UPS):
(Part 1) : 2014	General and safety requirements
(Part 3) : 2014/ IEC 62040-3 : 2011	Method of specifying the performance and test requirements
16463 (Part 12) : 2016/IEC 61643-12 : 2008	Surge-protective device connected to low-voltage power distribution systems: Part 12 Performance requirements and testing methods
IEC 60050-195	International Electrotechnical Vocabulary — Part 195: Earthing and protection against electric shock
IEC 60050-826	International Electrotechnical Vocabulary — Part 826: Electrical installations
IEC 60073 : 1996	Basic and safety principles for man-machine interface, marking and identification — Coding principles for indication devices and actuators
IS/IEC 60079 (All Parts)	Electrical apparatus for explosive gas atmospheres
IEC 60245-3	Rubber insulated cables — Rated voltages up to and

IS No./ International Standards	*Title*
	including 450/750 V — Part 3: Heat resistant silicone insulated cables
IEC 60255-22-1 : 1988	Electrical relays — Part 22: Electrical disturbance tests for measuring relays and protection equipment, Section 1: 1 MHz burst disturbance tests
IEC 60269-3	Low-voltage fuses — Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications) — Examples of standardized systems of fuses A to F
IEC 60287 (All Parts)	Electric cables — Calculation of the current rating
IEC 60331 (All Parts)	Tests for electric cables under fire conditions — Circuit integrity
IEC 60331-11	Tests for electric cables under fire conditions — Circuit integrity — Part 11: Apparatus — Fire alone at a flame temperature of at least 750 °C
IEC 60331-21	Tests for electric cables under fire conditions — Circuit integrity — Part 21: Procedures and requirements — Cables of rated voltage up to and including 0.6/1.0 kV
IEC 60332 (All Parts)	Tests on electric and optical fiber cables under fire conditions
IEC 60332-1-1	Tests on electric and optical fibre cables under fire conditions — Part 1-1: Test for vertical flame propagation for a single insulated wire or cable — Apparatus
IEC 60332-1-2	Tests on electric and optical fibre cables under fire conditions — Part 1-2: Test for vertical flame propagation for a single insulated wire or cable — Procedure for 1 kW pre-mixed flame
IEC 60364 (All parts)	Low-voltage electric installations
IEC 60445	Basic and safety principles for man-machine interface, marking and identification — Identification of equipment terminals and of terminations of certain designated conductors, including general rules for an alphanumeric system
IEC 60446	Basic and safety principles for man-machine interface, marking and identification — Identification of conductors by colours or numerals
IEC 60447 : 1993	Man-machine interface (MMI) — Actuating principles
IEC 60449	Voltage bands for electrical installations of buildings
IS/IEC 60479-1 : 2005	Effects of current on human beings and livestock — Part 1: General aspects
IEC 60502 (All Parts)	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1.2 kV) up to 30 kV (U_m = 36 kV)
IS/IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60570	Electrical supply track systems for luminaires
IEC 60598-2-13 : 2006	Luminaires — Part 2-13: Particular requirements — Ground recessed luminaires
IEC 60598-2-22 : 1997	Luminaires — Part 2-22: Particular requirements — Luminaires for emergency lighting
IEC 60598-2-24	Luminaires — Part 2-24: Particular requirements — Luminaires with limited surface temperatures
IEC 60670-21	Boxes and enclosures for electrical accessories for household and similar fixed electrical installations — Part 21: Particular requirements for boxes and enclosures with provision for suspension means
IEC 60702 (All Parts)	Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V
IEC 60724	Short-circuit temperature limits of electric cables with rated voltages of 1 kV (U_m = 1.2 kV) and 3 kV (U_m = 3.6 kV)
IS/IEC 60898 (All Parts)	Electrical accessories — Circuit-breakers for overcurrent protection for household and similar installations
IS/IEC 60947-2	Low-voltage switchgear and controlgear — Part 2: Circuit-breakers

IS No./ International Standards	*Title*
IS/IEC 60947-3	Low-voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
IEC 60947-6-2	Low-voltage switchgear and controlgear — Part 6-2: Multiple function equipment — Control and protective switching devices (or equipment) (CPS)
IEC 60947-7 (All Parts)	Low-voltage switchgear and controlgear — Part 7: Ancillary equipment
IEC 60949	Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects
IEC 60998 (All Parts)	Connecting devices for low-voltage circuits for household and similar purposes — Part 1: General requirements
IEC 61000-2 (All Parts)	Electromagnetic compatibility (EMC) — Part 2: Environment
IEC 61009 (All Parts)	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)
IEC 61024-1 : 1990	Protection of structures against lightning — Part 1: General principles
IEC 61082 (All Parts)	Preparation of documents used in electrotechnology
IEC 61140	Protection against electric shock — Common aspects for installation and equipment
IEC 61312-1 : 1995	Protection against lightning electromagnetic impulse — Part 1: General principles
IEC/TS 61312-2 : 1999	Protection against lightning electromagnetic impulse (LEMP) — Part 2: Shielding of structures, bonding inside structures and earthing
IEC/TS 61312-3 : 2000	Protection against lightning electromagnetic impulse — Part 3: Requirements of surge protective devices (SPDs)
IEC 61346-1 : 1996	Industrial systems, installations and equipment and industrial products — Structuring principles and reference designations — Part 1: Basic rules
IEC 61439-1	Low-voltage switchgear and controlgear assemblies — Part 1: General rules
IEC 61439-2	Low-voltage switchgear and controlgear assemblies — Part 2: Power switchgear and controlgear assemblies
IEC 61534 (All Parts)	Power track systems
IEC 61535	Installation couplers intended for permanent connection in fixed installations
IEC 61537	Cable management — Cable tray systems and cable ladder systems
IS/IEC 61557-1 : 2007	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. — Equipment for testing, measuring or monitoring of protective measures: Part 1 General requirements
IS/IEC 61557-2 : 2007	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 v d.c. — Equipment for testing, measuring or monitoring of protective measures: Part 2 Insulation resistance
IEC 61577-6	Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. — Equipment for testing, measuring or monitoring of protective measures — Part 6: Residual current devices (RCD) in TT and TN systems
IEC 61558-2-1	Safety of power transformers, power supplies, reactors and similar products — Part 2-1: Particular requirements for tests for separating transformers and power supplies incorporating separating transformers for general applications
IEC 61558-2-4	Safety of power transformers, power supply units and similar Part 2-4: Particular requirements for isolating transformers for general use
IS/IEC 61558-2-6 : 1997	Safety of power transformers, power supply units and similar — Part 2-6: Particular requirements for safety isolating transformers for general use

IS No./ International Standards	*Title*
IEC 61558-2-15	Safety of power transformers, power supply units and similar — Part 2-15: Particular requirements for isolating transformers for the supply of medical locations
IEC 61643 (All Parts)	Low-voltage surge protective devices
IEC 61643-1 : 1998	Surge-protective device connected to low-voltage power distribution systems — Part 1: Performance requirements and testing methods
IEC 61936-1	Power installations exceeding 1 kV a.c. — Part 1: Common rules
IEC 61995 (All Parts)	Devices for the connection of luminaires for household and similar purposes
IEC Guide 104	The preparation of safety publications and the use of basic safety publications and group safety publications
IS/IEC 62305-1 : 2010	Protection against lightning — Part 1: General principles
IS/IEC 62305-3 : 2010	Protection against lightning — Part 3: Physical damage to structures and life hazard
IS/IEC 62305-4 : 2010	Protection against lightning — Part 4: Electrical and electronic systems within structures
IS/ISO 834	Fire-resistance tests — Elements of building construction
IS/ISO 8528-12 : 1997	Reciprocating internal combustion engine driven alternating current generating sets — Part 12: Emergency power supply to safety services
ISO 30061 : 2007	Emergency lighting

3 TERMINOLOGY

For the purposes of this standard, the following definitions shall apply. As far as possible, the definitions below are aligned with IS 1885 and the fundamental International vocabulary IEC 60050-826.

3.1 Accessory — A device, other than current-using equipment, associated with such equipment or with the wiring of an installation.

3.2 Agricultural and Horticultural Premises — Rooms, location or areas where live stocks are kept; feed, fertilizers, vegetable and animal products are produced, stored, prepared or processed; plants are grown, such as greenhouse.

3.3 Ambient Temperature — The temperature of the air or other medium where the equipment is to be used.

3.4 Appliance — An item of current-using equipment other than a luminaire or an independent motor.

3.5 Arm's Reach — A zone extending from any point on a surface where persons usually stand or move about, to the limits which a person can reach with the hand in any direction without assistance.

NOTE — This space is by convention, limited as shown in Fig. 1.

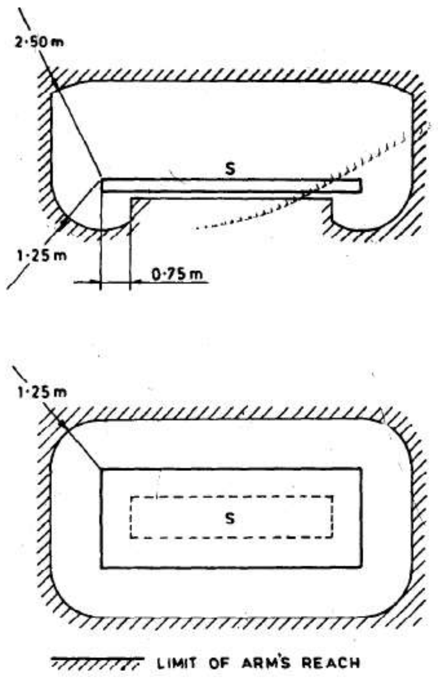


FIG. 1 ARM'S REACH

3.6 Back-up Protection — Protection which is intended to operate when a system fault is not cleared or abnormal condition not detected in the required time, because of failure or inability of other protection to operate or failure of appropriate circuit-breaker to trip.

3.7 Barrier V— A part providing a defined degree of protection against contact with live parts, from any usual direction of access.

3.8 Basic Insulation — Insulation applied to live parts to provide basic protection against electric shock and which does not necessarily include insulation used exclusively for functional purpose.

3.9 Basic Protection — Protection against electric shock under fault-free condition.

NOTE — For low voltage installations, systems and equipment, basic protection generally corresponds to protection against direct contact that is "contact of persons or live parts".

3.10 Basin of Fountain — A basin not intended to be occupied by persons and which cannot be accessed

(reached by persons) without the use of ladders or similar means. For basins of fountains which may be occupied by persons, the requirement of swimming pools applies.

3.11 Bonding Conductor — A protective conductor providing equipotential bonding.

3.12 Bonding Network (BN) — A set of interconnected conductive parts that provide a path for current at frequencies from direct current (d.c.) to radio frequency (RF) intended to divert, block or impede the passage of electromagnetic energy.

3.13 Bonding Ring Conductor (BRC) —A bus earthing conductor in the form of a closed ring.

NOTE — Normally the bonding ring conductor, as part of the bonding network, has multiple connections to the common bonding network (CBN) that improves its performance.

3.14 Booth — Non-stationary unit intended to accommodate equipment generally for pleasure or demonstration purpose.

3.15 Building Voids, Accessible — Space within the structure or the components of a building accessible only at certain points.

NOTES

1 Examples are: Space within partitions, suspended floors, ceilings and certain types of window frame, door frame and architraves.

2 Specially formed building voids are also as ducts.

3.16 Building Void, Non-accessible — A space within the structure or the components of building which has no ready means of access.

3.17 Buried Direct — A cable laid in the ground in intimate contact with the soil.

3.18 Bunched — Cables are said to be bunched when two or more cables are contained within a single conduit, duct, ducting, or trunking or, if not enclosed, are not separated from each other.

3.19 Busbar Trunking System — A type-tested assembly, in the form of an enclosed conductor system comprising solid conductors separated by insulating materials. The assembly may consist of units such as:

a) Busbur trunking units, with or without tap-off facilities;
b) Tap-off units where applicable; and
c) Phase-transposition, expansion, building-movement, flexible, end-feeder and adaptor units.

3.20 Bypass Equipotential Bonding Conductor — Bonding conductor connected in parallel with the screens of cables.

3.21 Cable Channel — An enclosure situated above or in the ground, open or ventilated or closed, and having dimensions which do not permit the access of persons but allow access to the conductor and/or cables throughout their length during and after installation.

NOTE — A cable channel may or may not form part of the building construction.

3.22 Cable Cleat — A component of a support system which consists of elements spread at intervals along the length of the cable or conduits and which mechanically retains the cable or conduit.

3.23 Cable Bracket — A cable support consisting of single devices fixed to elements of building or plant construction.

3.24 Cable Coupler — A means enabling the connection, at will, of two flexible cables. It consists of a connector and a plug.

3.25 Cable Ducting — A manufactured enclosure of metal or insulating material, other than conduit or cable trunking, intended for the protection of cables which are drawn-in after erection of the ducting, but which is not specifically intended to form part of a building structure.

3.26 Cable Trunking — A factory made closed support and protection system into which conductors and/or cables are laid after removal of the cover.

3.27 Cable Tunnel — An enclosure (corridor) containing supporting structures for conductors and/or cables and joints and whose dimensions allow free access to persons throughout the entire length.

3.28 Cable Tray — A cable support consisting of a continuous base with raised edges and no covering. A cable tray is considered to be non-perforated, where less than 30 percent of the material is removed from the base.

3.29 Cable Ladder — A cable support occupying less than 10 percent of the plan area and consisting of a series of supporting elements rigidly fixed to each other or to a main supporting member or members.

3.30 Circuit —An assembly of electrical equipment supplied from the same origin and protected against overcurrent by the same protective devices. Certain types of circuit are categorised as follows:

a) *Category 1 Circuit* — A circuit (other than a fire alarm or emergency lighting circuit) operating at low voltage and supplied directly from a mains supply system.
b) *Category 2 Circuit* — With the exception of fire alarm and emergency lighting circuits, any circuit for telecommunication (for example, radio, telephone, sound distribution, intruder alarm, bell, call and data transmission circuits)

which is supplied from a safety source.

c) *Category 3 Circuit* — A fire alarm circuit or an emergency lighting circuit.

3.31 Cartridge Fuse Link — A device comprising a fuse element or several fuse elements connected in parallel enclosed in a cartridge usually filled with an arc-extinguishing medium and connected to terminations. The fuse link is the part of a fuse which requires replacing after the fuse has operated.

3.32 Circuit Breaker — A mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions and also of making, carrying for as specified, and breaking currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A circuit breaker is usually intended to operate infrequently, although some types are suitable for frequent operation.

3.33 Circuit Breaker Linked— A circuit breaker the contacts of which are so arranged as to make or break all poles simultaneously or in a definite sequence.

3.34 Class I Equipment — Equipment in which protection against electric shock does not rely on basic insulation only, but which includes an additional safety precaution in such a way that means are provided for the connection of exposed conductive parts to a protective conductor in the fixed wiring of installation in such a way that accessible conductive parts may not become live in the event of a failure of basic installation.

NOTE — For information on classification of equipment with regard to means provided for protection against electric shock, *see* IEC 61140.

3.35 Class II Equipment — Equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions, such as double or reinforced insulation are provided, there being no provision for the connection of exposed metal work of the equipment to a protective conductor, and no reliance upon precautions to be taken in the fixed wiring of the installation.

3.36 Class III Equipment — Equipment in which protection against electric shock relies on supply at SELV and in which voltages higher than those of SELV are not generated.

3.37 Cold Tail — The interface between the fixed installation and a heating unit.

3.38 Combustible — Capable of burning.

3.39 Common Equipotential Bonding System, Common Bonding Network — Equipotential bonding system providing both protective equipotential bonding and functional equipotential bonding.

3.40 Competent Person —A person who possesses sufficient technical knowledge, relevant practical skill and experience for the nature of the electrical work undertaken and is able at all the time to prevent danger and, where appropriate, injury to him/herself and others.

3.41 Conduit —A part of a closed wiring system a circular or non-circular cross-section for conductors and/or cables in electrical installations, allowing them to be drawn in and/or replaced. Conduits should be sufficiently closed-jointed so that the conductors can only be drawn in and not inserted laterally.

3.42 Confined Conductive Location — Allocation having surfaces which are mainly composed of extraneous conductive parts and which are of such dimensions that movement is restricted to such an extent that contact with surfaces is difficult to avoid (for example in a boiler).

3.43 Connector — The part of a cable coupler or of an appliance coupler which is provided with female contact and is intended to be attached to the flexible cable connected to the supply.

3.44 Consumer Unit (may also be known as a consumer control unit or electricity control unit) — A particular type of distribution board comprising a type-tested co-ordinated assembly for the control and distribution of electrical energy, principally in domestic premises, incorporating manual means of double-pole isolation on the incoming circuit(s) and an assembly of one or more fuses, circuit-breakers, residual current operated devices or signalling and other devices proven during the type-test of the assembly as suitable for such use.

3.45 Continuous Operating Voltage (Uc) — Maximum r.m.s voltage which may be continuously applied to an SPD's mode of protection. This is equal to rated voltage.

3.46 Conventional Impulse Withstand Voltage — The peak value of an impulse test voltage at which insulation does not show any disruptive discharge, when subjected to a specified number of applications of impulses of this value, under specified condition.

3.47 Conventional Touch Voltage Limit — Maximum value of the touch voltage which is permitted to be maintained indefinitely in specified conditions of external influences.

3.48 Conventional Operating Current (of a Protective Device) — A specified value of the current which causes the protective device to operate within a specified time, designated conventional time.

NOTES

1 For fuses this current is called the conventional fusing current. For circuit breakers this current is called the conventional operating current.

2 The conventional operating current is greater than the rated current or current setting of the device and the conventional time varies according to the type and rated current of the protective device.

3.49 Current Carrying Capacity of a Conductor — The maximum current which can be carried by a conductor under specified conditions without its steady state temperature exceeding a specified value.

3.50 Current Using Equipment — Equipment which converts electrical energy into another form of energy, such as light, heat, or motive power.

3.51 Danger — Danger to health or danger to life or limb from shock, burn or injury from mechanical movement to persons (and livestock where present), or from fire attendant upon the use of electrical energy.

3.52 Design Current (of a Circuit) — The magnitude of the current intended to be carried by the circuit in normal service.

3.53 Direct Contact — Contact of persons or livestock with live parts which may result in electric shock.

3.54 Disconnector — A mechanical switching device which, in the open position, complies with the requirements specified for the isolation function.

NOTES

1 A disconnector is otherwise known as isolator.

2 A disconnector is capable of opening and closing a circuit when either a negligible current is broken or made, or when no significant change in the voltage across the terminals of each pole of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying for a specified time, current under abnormal conditions such as those of short-circuit.

3.55 Discrimination — Ability of a protective device to operate in preference to another protective device in series.

3.56 Distribution Circuit (of Buildings) — A circuit supplying a distributing board.

3.57 Double Insulation —Insulation comprising both basic insulation and supplementary insulation.

3.58 Duct — A closed passage way formed under ground or in a structure and intended to receive one or more cables which may be drawn in.

3.59 Ducting (*see* **3.25**)

3.60 Earth — The conductive mass of the earth, whose electric potential at any point is conventionally taken as zero.

3.61 Earth Electrode Network — Part of an earthing arrangement comprising only the earth electrodes and their interconnections.

3.62 Earth Fault Current — A current resulting from a fault of negligible impedance between a line conductor and an exposed conductive part or a protective conductor.

3.63 Earth Electrode Resistance — The resistance of an earth electrode to earth.

3.64 Earth Fault Loop Impedance — The impedance of the earth fault current loop (phase to earth loop) starting and ending at the point of earth fault. This impedance is denoted by the symbol Z. The earth fault loop comprises the following, starting at the point of fault:

a) the circuit protective conductor;
b) the consumer's earthing terminal and earthing conductor, and for TN systems, the metallic return path;
c) for TT and IT systems, the earth return path;
d) the path through the earth neutral point of the transformer;
e) the transformer winding; and
f) the line conductor from the transformer to the point of fault.

3.65 Earth Leakage Current — A current which flows to earth, or to extraneous conductive parts, in a circuit which is electrically sound.

NOTE — This current may have a capacitive component including that resulting from the deliberate use of capacitors.

3.66 Earthing — Connection of the exposed conductive parts of an installation to the main earthing terminal of that installation.

3.67 Earthing Resistance, Total — The resistance between the main earthing terminal and the earth.

3.68 Earthed Concentric Wiring — A wiring system in which one or more insulated conductors are completely surrounded throughout their length by a conductor, for example a sheath, which acts as a PEN conductor.

3.69 Earthing Conductor — A protective conductor connecting the main earth terminal (or equipotential bonding conductor of an installation when there is no earth bus) to an earth electrode or to other means of earthing.

3.70 Electric Shock — A dangerous patho-physiological effect resulting from the passing of an electric current through a human body or an animal.

3.71 Electrical Equipment (*abb*: Equipment) — Any item for such purposes as generation, conversion, transmission, distribution or utilization of electrical energy, such as machines, transformers, apparatus, measuring instruments, protective devices, wiring

materials, accessories, and appliances.

3.72 Electrical Installation (of a Building) — An assembly of associated electrical equipment to fulfil a specific purpose or purposes and having coordinated characteristics.

3.73 Electrically Independent Earth Electrodes — Earth electrodes located at such a distance from one another that the maximum current likely to flow through one of them does not significantly affect the potential of the other(s).

3.74 Electrical Source for Safety Services — Electrical source intended to be used as part of an electrical supply system for safety services.

3.75 Electrical Supply System for Safety Services — A supply system intended to maintain the operation of essential parts of an electrical installation and equipment:

a) For health and safety of persons and livestock, and
b) To avoid damage to the environment and to other equipment.

NOTE — The supply system includes the source and the circuit(s) up to the terminals of the electrical equipment.

3.76 Electrode Boiler (or Electrode Water Heater) — Equipment for the electrical heating of water or electrolyte by the passage of an electric current between electrodes immersed in the water or electrolyte.

3.77 Emergency Switching — Rapid cutting off of electrical energy to remove any hazard to persons, livestock, or property which may occur unexpectedly.

3.78 Enclosure — A part providing protection of equipment against certain external influences and, in any direction, protection against direct contact.

3.79 Equipotential Bonding — Electrical connection putting various exposed conductive parts and extraneous conductive parts at a substantially equal potential.

NOTE — In a building installation equipotential bonding conductors shall interconnect the following conductive parts:

a) Protective conductor,

b) Earth continuity conductor, and

c) Risers of air-conditioning system and heating systems (if any).

3.80 Exposed Conductive Part — A conductive part of electrical equipment, which can be touched and which is not normally live, but which may become live under fault conditions.

3.81 External Influence — Any influence external to an electrical installation which affects the design and safe operation of that installation.

3.82 Extraneous Conductive Part — A conductive part got forming part of the electrical installation and liable to introduce a potential, generally the earth potential.

3.83 Factory Built Assembly (of LV Switchgear and Controlgear) — *See* IS 8623 (Part 1).

3.84 Fault — A circuit condition in which current flows through an abnormal or unintended path. This may result from an insulation failure or a bridging of insulation. Conventionally the impedance between live conductors or between lives conductors and exposed or extraneous conductive parts at the fault position is considered negligible.

3.85 Fault Current — A current resulting from a fault.

3.86 Fault Protection — Protection against electric shock under single fault conditions.

NOTE — For low voltage installation, systems and equipment, fault protection generally corresponds to protection against in direct contact, mainly with regards to failure of basic insulation. Indirect contact is "contact of persons or livestock with exposed-conductive parts which have become live under fault conditions."

3.87 Final Circuit — A circuit connected directly to current using equipment, or to socket outlets or other outlet points for the connection of such equipment.

3.88 Fire

a) A process of combustion characterized by the emission of heat and effluent accompanied by smoke, and/or flame and/or glowing.
b) Rapid combustion spreading uncontrolled in time and space.

3.89 Fixed Equipment — Equipment fastened to a support or otherwise secured.

3.90 Flammability — Ability of a material or product to burn with a flame under specified test condition.

3.91 Functional Bonding Conductor — Conductor provided for functional equipotential bonding.

3.92 Functional Earthing — Connection to earth necessary for proper functioning of electrical equipment.

3.93 Functional Extra-low Voltage (FELV) — An extra-low voltage system in which not all of the protective measures required for SELV or PELV have been applied.

3.94 Fuse — A device which, by melting of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device.

3.95 Fuse Carrier — The movable part of a fuse designed to carry a fuse link.

3.96 Fuse Element — A part of a fuse designed to melt when the fuse operates.

3.97 Fuse Link — A part of fuse, including the fuse element(s), which requires replacement by a new or renewable fuse link after the fuse has operated and before the fuse is put back into service.

3.98 Gas Installation Pipe — Any pipe, not being a service pipe or pipe comprised in a gas appliance, for conveying gas for a particular consumer and including any associated valve or other gas fitting.

3.99 Hand-Held Equipment — Portable equipment intended to be held in the hand during normal use, in which the motor, if any, forms an integral part of the equipment.

NOTE — A hand held equipment is an item of equipment, the functioning of which requires constant manual support or guidance.

3.100 Hazardous-Live Part — A live part which can give, under certain condition of external influence, an electric shock.

3.101 Impulse Current — A parameter used for the classification test for SPDs; it is defined by three elements, a current peak value, a charge Q and a specific energy W/R.

3.102 Impulse Withstand Voltage— The highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified condition.

3.103 Indirect Contact — Contact of persons or livestock with exposed conductive parts made live by a fault and which may result in electric shock.

3.104 Ignitability — Measure of the ease with which a specimen can be ignited due to the influence of an external source, under specified test condition.

3.105 Ignition — Initiation of combustion.

3.106 Installations (*see* **3.72**).

3.107 Overcurrent — A current exceeding the rated value. For conductors, the rated value is the current carrying capacity.

3.108 Overcurrent Detection —A method of establishing that the value of current in a circuit (or wall) such that in the event of direct contact exceeds a predetermined value for a specified time with a live part, a person standing on the floor (or touching the wall) cannot be traversed by a shock current flowing to the floor (or wall).

3.109 Insulation — Suitable non-conductive material enclosing surrounding or supporting a conductor.

NOTE — *See also* the definitions for basic insulation, double insulation, reinforced insulation and supplementary insulation.

3.110 Insulation Co-ordination — The selection of the electric strength of equipment in relation to the voltages which can appear on the system for which the equipment is intended, taking into account the service environment and the characteristics of the available protective devices.

3.111 Isolation — Cutting off an electrical installation, a circuit, or an item of equipment from every source of electrical energy.

3.112 Isolator — A mechanical switching device which, in the open position, complies with the requirements specified for the isolating function. An isolator is otherwise known as a disconnector.

3.113 Leakage Current — Electric current in an unwanted conductive path under normal operating conditions.

3.114 Lighting Protection Zone — Zone where the lightning electromagnetic environment is defined.

3.115 Line Conductor — A conductor of an a.c. system for the transmission of electrical energy other than a neutral conductor or a PEN conductor. This also means the equivalent conductor of a d.c. system unless otherwise specified in the Regulations.

3.116 Live Part — A conductor or conductive part intended to be energized in normal use including a neutral conductor but, by convention, not a PEN conductor.

3.117 Low Voltage (*see* **3.187**).

3.118 Luminaire — Equipment which distributes, filters or transforms the light from one or more lamps, and which includes any parts necessary for supporting, fixing and protecting the lamps, but not the lamps themselves, and, where necessary, circuit auxiliaries together with the means for connecting them to the supply

NOTE — For the purposes of this code a batten lampholder, or a lampholder suspended by flexible cord, is a luminaire.

3.119 Luminaire Supporting Coupler (LSC) — A means comprises of LSC outlet and an LSC connector, providing mechanical support for a luminaire and the electrical connection to and disconnection from a fixed wiring installation.

3.120 Low-Voltage Switchgear and Controlgear Assembly —A combination of one or more low voltage switching devices together with associated control, measuring, signalling, protective, regulating equipment,

etc, completely assembled under the responsibility of the manufacturer with all the internal electrical and mechanical inter-connections and structural parts. The components of the assembly may be electromechanical or electronic.

3.121 Main Earthing Terminal — The terminal or bar which is the equipotential bonding conductor of protective conductors, and conductors for functional earthing, if any, to the means of earthing.

3.122 Mechanical Maintenance — The replacement, refurbishment or cleaning of lamps and non-electrical parts of equipment, plant and machinery.

3.123 Meshed Bonding Network (MESH-BN) — Bonding network in which all associated equipment frames, racks and cabinets and usually the d.c. power return conductor are bonded together as well as at multiple points to the CBN and may have the form of a mesh.

3.124 Minimum Illumination — Illumination for emergency lighting at the end of rated operating time.

3.125 Minor Works — Additions and alterations to an installation that do not extend to the provision of a new circuit**.**

3.126 Mobile Equipment — Electrical equipment which is moved while in operation or which can be easily moved from one place to another while connected to the supply.

3.127 Monitoring — Observation of the operation of a system or part of a system to verify correct functioning or detect incorrect functioning by measuring system variables and comparing the measured value with the specified value.

3.128 Neutral Conductor (Symbol N) — A conductor connected to the neutral point of a system and capable of contributing to the transmission of electrical energy.

The term also means the equivalent conductor of an IT or d.c. system unless otherwise specified in the regulations and also identifies either the mid-wire of a three-wire d.c. circuit or the earthed conductor of a two-wire earthed d.c. circuit.

3.129 Non-flame Propagating Component — Component which is liable to ignite, as a result of an applied flame, but in which the flame does not propagate and which extinguishes itself within a limited time after the flame is removed.

3.130 Obstacle — A part preventing unintentional contact with live parts but not preventing deliberate contact.

3.131 Origin of an Electrical Installation — The point at which electrical energy is delivered to an installation.

NOTE — An electrical installation may have more than one origin.

3.132 Overcurrent — A current exceeding the rated value. For conductors the rated value is the current carrying capacity.

3.133 Overcurrent Detection — A method of establishing that the value of current in a circuit exceeds a predetermined value for a specified length of time.

3.134 Overload Current (of a Circuit) — An overcurrent occurring in a circuit in the absence of an electrical fault.

3.135 PEL Conductor —A conductor combining the function of both a protective earthing and a line conductor.

3.136 PELV (Protective Extra-low Voltage) — An extra-low voltage system which is not electrically separated from earth, but which otherwise satisfies all the requirements for SELV.

3.137 PEM Conductor — A conductor combining the function of both a protective earthing conductor and a midpoint conductor.

3.138 PEN Conductor — A conductor combining the functions of both protective conductor and neutral conductor.

3.139 Phase Conductor — A conductor of an a.c. system for the transmission of electrical energy, other than a neutral conductor.

NOTE — The term also means the equivalent conductor of a d.c. system unless otherwise specified in this code.

3.140 Plug — A device, provided with contact pins, which is intended to be attached to a flexible cable, and which can be engaged with a socket outlet or with a connector.

3.141 Point (in Wiring) — A termination of the fixed wiring intended for the connection of current using equipment.

3.142 Portable Equipment — Equipment which is moved while in operation or which can easily be moved from one place to another while connected to the supply.

3.143 Powertrack — A system component, which is generally a linear assembly of spaced and supported busbars, providing electrical connection of accessories.

3.144 Powertrack System (PT System) — An assembly of system components including a powertrack by which accessories may be connected to an electrical supply at one or more points (predetermined or otherwise) along the powertrack.

NOTE — The maximum current rating of a powertrack system is 63A.

3.145 Prospective Fault Current (I_{pf}) — The value of overcurrent at a given point in a circuit resulting from a fault of negligible impedance between live conductor having a difference of potential under normal operating conditions, or between a live conductor and an exposed conductive part.

3.146 Prospective Touch Voltage — The highest touch voltage liable to appear in the event of a fault of negligible impedance in the electrical installation.

3.147 Protective Conductor — A conductor used for some measures of protection against electric shock and intended for connecting together any of the following parts:

a) Exposed conductive parts,
b) Extraneous conductive parts,
c) The main earthing terminal, and
d) The earthed point of the source, or an artificial neutral.

3.148 Protective Conductor Current —Electric current appearing in a protective conductor, such as leakage current or electric current resulting from an insulation fault.

3.149 Protective Earthing —Earthing of a point or points in a system or in equivalent for the purposes of safety.

3.150 Protective Euqipotential Bonding — Equipotential bonding for the purpose of safety.

3.151 Protective Multiple Earthing (PME) —An earthing arrangement, found in TN-C-S systems, in which the supply neutral conductor is used to connect the earthing conductor of an installation with Earth.

3.152 Protective Separation — Separation of one electric circuit from another by means of:

a) Double insulation,
b) Basic insulation and electrically protective screening (shielding), or
c) Reinforced insulation.

3.153 Rated Current —Value of current used for specification purposes, established for a specified set of operating conditions of a component, device, equipment or system.

3.154 Rated Impulse Withstand Voltage Level (U_w) —The level of impulse withstand voltage assigned by the manufacturer to the equipment, or to part of it, characterizing the specified withstand capability of its insulation against overvoltages.

3.155 Reinforced Insulation — Single insulation applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant standard.

NOTE — The term 'single insulation' does not imply that the insulation must be one-homogeneous piece. It may comprise several layers which cannot be tested singly as supplementary or basic insulation.

3.156 Residual Current — The algebraic sum of the instantaneous values of current flowing through all live conductors of a circuit at a point of the electrical installation.

3.157 Residual Current Device (RCD) — A mechanical switching device or association of devices intended to cause the opening of the contacts when the residual current attains a given value under specified conditions.

3.158 Residual Current Operated Circuit-Breaker with Integral Overcurent Protection (RCBO) —A residual current operated switching device designed to perform the functions of protection against overload and/or short-circuit.

3.159 Residual Current Operated Circuit-Breaker without Integral Overcurrent Protection (RCCB) —A residual current operated switching device not designed to perform the functions of protection against overload and/or short-circuit.

3.160 Residual Operating Current — Residual current which causes the residual current device to operate under specified conditions.

3.161 Resistance Area (for an Earth Electrode only) — The surface area of ground (around an earth electrode) on which a significant voltage gradient may exist.

3.162 Response Time —The time that elapses between the failure of the normal power supply and the of the auxiliary power supply to energize the equipment

3.163 Ring Final Circuit —A final circuit arranged in the form of a ring and connected to a single point of supply.

3.164 Safety Service —An electrical system for electrical equipment provided to protect or warn persons in the event of a hazard, or essential to their evacuation from a location.

3.165 SELV (Separated Extra Low-Voltage) — An extra low-voltage system which is electrically separated from earth and from other system in such a way that a single fault cannot give rise to the risk of electric shock.

3.166 Shock Current —A current passing through the body of a person or an animal and having characteristics likely to cause dangerous patho-physiological effects.

3.167 Short-Circuit Current — An overcurrent resulting from a fault of negligible impedance between live conductors having a difference in potential under normal operating conditions.

3.168 Simple Separation —Separation between circuits or between a circuit and earth by means of basic insulation.

3.169 Simultaneously Accessible Parts — Conductors or conductive parts which can be touched simultaneously by a person or, where applicable by livestock.

NOTE — In the context of protection against direct contacts a live part may be accessible with:

a) another live part, or

b) an exposed conductive part, or

c) an extraneous conductive part, or

d) a protective conductor.

The following may constitute simultaneously accessible parts in the context of protection against indirect contacts:

a) Exposed conductive parts,

b) Extraneous conductive parts, and

c) Protective conductors.

It should be noted that the word touched signifies any contact with any part of the body (hand, foot, head, etc).

3.170 Skilled Person —A person with technical knowledge or sufficient experience to enable him/her to avoid dangers which electricity may create.

3.171 Socket Outlet — A device, provided with female contacts, which is intended to be installed with the fixed wiring, and intended to receive a plug.

NOTE — A luminaire track system is not regarded as a socket outlet system.

3.172 Space Factor — The ratio (expressed as a percentage) of the sum of the overall cross-sectional areas of cables (including insulation and sheath) to the internal cross-sectional area of the conduit or other cable enclosure in which they are installed. The effective overall cross-sectional area of a non-circular cable is taken as that of a circle of diameter equal to the major axis of the cable.

3.173 Spur — A branch cable connected to a ring or radial final circuit.

3.174 Standby Supply System —A system intended to maintain supply to the installation or part thereof, in case of interruption of the normal supply, for reasons other than safety of persons.

NOTE — Standby supplies are necessary, for example, to avoid interruption of continuous industrial processes or data processing.

3.175 Stationary Equipment — Either fixed equipment or equipment not provided with a carrying handle and having such a mass that it cannot easily be moved.

3.176 Supplementary Insulation — Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

3.177 Surge Current — A transient wave appearing as an overcurrent caused by a lightning electromagnetic impulse.

3.178 Surge Protective Devices (SPD) — A device that is intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component.

3.179 Switch — A mechanical switching device capable of making, carrying and breaking current under normal circuit conditions, which may include specified operating overload conditions, and also of carrying for a specified time currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A switch may also be capable of making, but not breaking, short-circuit currents.

3.180 Switch, Linked — A switch, the contacts of which are so arranged as to make or break all poles simultaneously or in a definite sequence.

3.181 Switch-disconnector — A switch which, in the open position, satisfies the isolating requirements specified for a disconnector.

NOTE — A switch-disconnector is otherwise known as an isolating switch.

3.182 Switchboard — An assembly of switchgear with or without instruments, but the term does not apply to a group of local switches in a final circuit.

NOTE — The term 'switchboard' includes a distribution board.

3.183 Switchgear — An assembly of main and auxiliary switching apparatus for operation, regulation, protection or other control of electrical installations.

3.184 System — An electrical system consisting of a single source or multiple sources running in parallel of electrical energy and an installation. Types of system are identified as follows, depending upon the relationship of the source, and of exposed-conductive parts of the installation, to Earth:

a) **TN system** — A system having one or more points of the source of energy directly earthed, the exposed conductive-parts of the installation being connected to that point by protective conductors.

b) **TN-C system** — A system in which neutral

and protective conductors are combined in a single conductor throughout the system.

c) **TN-S system** — A system having separate neutral and protective conductor throughout the system.

d) **TN-C-S system** — A system in which neutral and protective conductors are combined in a single conductor in part of the system.

e) **TT system** — A system having one point of the source of energy directly earthed, the exposed-conductive-parts of the installation being connected to the earth electrodes electrically independent of the earth electrodes of the source.

f) **IT system** — A system having no direct connection between live parts and Earth, the exposed-conductive-parts of the electrical installation being earthed.

NOTE — The types of systems depending upon the relationship to the source and of the exposed conductive parts of the installation to earth are defined in IS 3043.

3.185 Temporary Overvoltage (UTOV) — A fundamental frequency overvoltage occurring on the network at a given location, of relatively long duration.

NOTES

1 TOVS may be caused by faults inside the LV system or inside the HV system.

2 Temporary overvoltages, typically lasting up to several seconds, usually originate from switching operations or faults (for example, sudden load rejection, single-phase faults, etc.) and/or from non-linearity (ferroresonance effects, harmonics, etc).

3.186 Touch Voltage — The potential difference between the ground potential rise (GPR) of a grounded metallic structure and the surface potential at the point where a person could be standing while at the same time having a hand in contact with the grounded metallic structure. Touch voltage measurements can be "open circuit"(without the equivalent body resistance included in the measurement circuit) or "closed circuit" (with the equivalent body resistance included in the measurement circuit) voltage by which an installation or part of an installation is designated.

3.187 Voltage Nominal (of an Installation) — Voltage by which an installation or part of an installation is designated.

4 FUNDAMENTAL PRINCIPLES, ASSESSMENT OF GENERAL CHARACTERISTICS

4.1 Protection for Safety

4.1.1 *General*

The requirements stated in **4.1.1** to **4.1.5** are intended to provide for the safety of persons, livestock and property against dangers and damage which may arise in the reasonable use of electrical installations. The requirements to provide for the safety of livestock are applicable in locations intended for them.

NOTE — In electrical installations, the following hazards may arise:

a) shock currents;

b) excessive temperatures likely to cause burns, fires and other injurious effects;

c) ignition of a potentially explosive atmosphere;

d) undervoltages, overvoltages and electromagnetic influences likely to cause or result in injury or damage;

e) power supply interruptions and/or interruption of safety services;

f) arcing, likely to cause blinding effects, excessive pressure, and/or toxic gases; and

g) mechanical movement of electrically activated equipment.

4.1.2 *Protection Against Electric Shock*

4.1.2.1 *Basic protection* (*protection against direct contact*)

NOTE — For low-voltage installations, systems and equipment, basic protection generally corresponds to protection against direct contact.

Protection shall be provided against dangers that may arise from contact with live parts of the installation by persons or livestock.

This protection can be achieved by one of the following methods:

a) preventing a current from passing through the body of any person or any livestock; and

b) limiting the current which can pass through a body to a non-hazardous value.

4.1.2.2 *Fault protection* (*protection against indirect contact*)

NOTE — For low-voltage installations, systems and equipment, fault protection generally corresponds to protection against indirect contact, mainly with regard to failure of basic insulation.

Protection shall be provided against dangers that may arise from contact with exposed - conductive-parts of the installation by persons or livestock.

This protection can be achieved by one of the following methods:

a) preventing a current resulting from a fault from passing through the body of any person or any livestock;

b) limiting the magnitude of a current resulting from a fault, which can pass through a body, to a non-hazardous value; and

c) limiting the duration of a current resulting from a fault, which can pass through a body, to a non-hazardous time period.

4.1.2.3 *Protection against thermal effects*

The electrical installation shall be so arranged to minimize the risk of damage or ignition of flammable materials due to high temperature or electric arc. In addition, during normal operation of the electrical equipment, there shall be no risk of persons or livestock suffering burns.

4.1.2.4 *Protection against overcurrent*

Persons and livestock shall be protected against injury

and property shall be protected against damage due to excessive temperatures or electromechanical stresses caused by any overcurrents likely to arise in conductors.

Protection can be achieved by limiting the overcurrent to a safe value or duration.

4.1.2.5 *Protection against fault currents*

Conductors, other than live conductors, and any other parts intended to carry a fault current shall be capable of carrying that current without attaining an excessive temperature. Electrical equipment, including conductors shall be provided with mechanical protection against electromechanical stresses of fault currents as necessary to prevent injury or damage to persons, livestock or property.

Live conductors shall be protected against over currents arising from faults by the methods given in **4.1.2.4**.

NOTE — Attention should particular be given to PE conductor and earthing conductor currents.

4.1.2.6 *Protection against voltage disturbances and measures against electromagnetic influences*

4.1.2.6.1 Persons and livestock shall be protected against injury and property shall be protected against any harmful effects as a consequence of a fault between live parts of circuits supplied at different voltages.

4.1.2.6.2 Persons and livestock shall be protected against injury and property shall be protected against damage as a consequence of overvoltages such as those originating from atmospheric events or from switching.

NOTE — For protection against direct lightning strikes, *see* IS/IEC 62305 series.

4.1.2.6.3 Persons and livestock shall be protected against injury and property shall be protected against damage as a consequence of undervoltage and any subsequent voltage recovery.

4.1.2.6.4 The installation shall have an adequate level of immunity against electromagnetic disturbances so as to function correctly in the specified environment. The installation design shall take into consideration the anticipated electromagnetic emissions, generated by the installation or the installed equipment, which shall be suitable for the current-using equipment used with, or connected to, the installation.

4.1.2.7 *Protection against power supply interruption*

Where danger or damage is expected to arise due to an interruption of supply, suitable provisions shall be made in the installation or installed equipment.

4.1.3 *Design*

4.1.3.1 *General*

For the design of the electrical installation, the following factors shall be taken into account to provide:

a) the protection of persons, livestock and property in accordance with **4.1**.
b) the proper functioning of the electrical installation for the intended use.

The information required as a basis for design is listed in **4.1.3.2** to **4.1.3.5**. The requirements with which the design shall comply are stated in **4.1.3.6** and **4.1.3.7**.

4.1.3.2 *Characteristics of available supply or supplies*

When designing electrical installations in accordance with this standard it is necessary to know the characteristics of the supply. Relevant information from the network operator is necessary to design a safe installation according to this standard. The characteristics of the power supply should be included in the documentation to show conformity with this standard. If the network operator changes the characteristics of the power supply this may affect the safety of the installation.

4.1.3.2.1 *Nature of current* — a.c. and/or d.c.

4.1.3.2.2 *Function of conductors*

a) for a.c.:
   1) line conductor(s);
   2) neutral conductor;
   3) protective conductor.
b) for d.c.:
   1) line conductor(s);
   2) midpoint conductor;
   3) protective conductor.

NOTE — The function of some conductors may be combined in a single conductor.

4.1.3.2.3 *Values and tolerances*

a) voltage and voltage tolerances;
b) voltage interruptions, voltage fluctuations and voltage dips;
c) frequency and frequency tolerances;
d) maximum current allowable;
e) earth fault loop impedance upstream of the origin of the installation; and
f) prospective short-circuit currents.

For standard voltages and frequencies, *see* IS 12360.

4.1.3.2.4 Protective provisions inherent in the supply, for example, system earthing or mid-point earthing.

4.1.3.2.5 Particular requirements of the supply undertaking.

4.1.3.3 *Nature of demand*

The number and type of circuits required for lighting,

heating, power, control, signalling, information and communication technology, etc shall be determined by:

a) location of points of power demand;
b) loads to be expected on the various circuits;
c) daily and yearly variation of demand;
d) any special conditions such as harmonics;
e) requirements for control, signalling, information and communication technology, etc; and
f) anticipated future demand if specified.

4.1.3.4 *Electric supply systems for safety services or standby electric supply systems*

a) Source of supply (nature, characteristics).
b) Circuits to be supplied by the electric source for safety services or the standby electrical source.

4.1.3.5 *Environmental conditions*

The design of the electrical installation shall take into account the environmental conditions to which it will be subjected [*see* **5.1** and IS 13736 (All Parts)].

4.1.3.6 *Cross-sectional area of conductors*

The cross-sectional area of conductors shall be determined for both normal operating conditions and for fault conditions according to:

a) their admissible maximum temperature;
b) the admissible voltage drop;
c) the electromechanical stresses likely to occur due to earth fault and short-circuit currents;
d) other mechanical stresses to which the conductors can be subjected;
e) the maximum impedance with respect to the functioning of the protection against fault currents; and
f) the method of installation.

NOTE — The items listed above concern primarily the safety of electrical installations. Cross-sectional areas greater than those required for safety may be desirable for economic operation.

4.1.3.7 *Type of wiring and methods of installation*

For the choice of the type of wiring and the methods of installation the following shall be taken into account:

a) the nature of the locations;
b) the nature of the walls or other parts of the building supporting the wiring;
c) accessibility of wiring to persons and livestock;
d) voltage;
e) the electromagnetic stresses likely to occur due to earth fault and short-circuit currents;
f) electromagnetic interference; and
g) other stresses to which the wiring can be subjected during the erection of the electrical installation or in service.

4.1.3.8 *Protective equipment*

The characteristics of protective equipment shall be determined with respect to their function which may be, for example, protection against the effects of:

a) overcurrent (overload, short-circuit),
b) earth fault current,
c) overvoltage, and
d) undervoltage and no voltage.

The protective devices shall operate at values of current, voltage and time which are suitably related to the characteristics of the circuits and to the possibilities of danger.

4.1.3.9 *Emergency control*

Where, in case of danger, there is the necessity for the immediate interruption of supply, an interrupting device shall be installed in such a way that it can be easily recognized and effectively and rapidly operated.

4.1.3.10 *Disconnecting devices*

Disconnecting devices shall be provided so as to permit switching and/or isolation of the electrical installation, circuits or individual items of apparatus as required for operation, inspection and fault detection, testing, maintenance and repair.

4.1.3.11 *Prevention of mutual detrimental influence*

The electrical installation shall be arranged in such a way that no mutual detrimental influence will occur between electrical installations and non-electrical installations.

4.1.3.12 *Accessibility of electrical equipment*

The electrical equipment shall be arranged so as to afford as may be necessary:

a) sufficient space for the initial installation and later replacement of individual items of electrical equipment; and
b) accessibility for operation, inspection and fault detection, testing, maintenance and repair.

4.1.3.13 *Documentation for the electrical installation*

Every electrical installation shall be provided with appropriate documentation.

4.1.4 *Selection of Electrical Equipment*

4.1.4.1 *General*

Every item of electrical equipment used in electrical

installations shall comply with such Indian Standards as are appropriate. Where there are no applicable standards, the item of equipment concerned shall be selected by special agreement between the person specifying the installation and the installer.

4.1.4.2 *Characteristics*

Every item of electrical equipment selected shall have suitable characteristics appropriate to the values and conditions on which the design of the electrical installation (*see* **4.1.3**) is based and shall, in particular, fulfil the following requirements:

a) *Voltage* — Electrical equipment shall be suitable with respect to the maximum steady-state voltage (r.m.s. value for a.c.) likely to be applied, as well as overvoltages likely to occur.

   NOTE — For certain equipment, it may be necessary to take account of the lowest voltage likely to occur.

b) *Current* — All electrical equipment shall be selected with respect to the maximum steady-state current (r.m.s. value for a.c.) which it has to carry in normal service, and with respect to the current likely to be carried in abnormal conditions and the period (for example, operating time of protective devices, if any) during which it may be expected to flow.

c) *Frequency* — If frequency has an influence on the characteristics of electrical equipment, the rated frequency of the equipment shall correspond to the frequency likely to occur in the circuit.

d) *Load factor* — All electrical equipment which is selected on the basis of its power characteristics shall be suitable for the duty demanded of the equipment taking into account the design service conditions.

4.1.4.3 *Conditions of installation*

All electrical equipment shall be selected so as to withstand safely the stresses and the environmental conditions (*see* **4.1.3.5**) characteristic of its location and to which it may be subjected. If, however, an item of equipment does not have by design the properties corresponding to its location, it may be used on condition that adequate additional protection is provided as part of the completed electrical installation.

4.1.4.4 *Prevention of harmful effects*

All electrical equipment shall be selected so that it will not cause harmful effects on other equipment or impair the supply during normal service including switching operations. In this context, the factors which can have an influence include, for example:

a) power factor;
b) inrush current;
c) asymmetrical load;
d) harmonics; and
e) transient overvoltages generated by equipment in the installation.

4.1.5 *Erection and Verification of Electrical Installations*

4.1.5.1 *Erection*

4.1.5.1.1 Good workmanship by competent persons and proper materials shall be used in the erection of the electrical installation. Electrical equipment shall be installed in accordance with the instructions provided by the manufacturer of the equipment.

4.1.5.1.2 The characteristics of the electrical equipment, as determined in accordance with **4.1.4.2**, shall not be impaired during erection.

4.1.5.1.3 Conductors shall be identified in accordance with IEC 60446. Where identification of terminals is necessary, they shall be identified in accordance with IEC 60445.

4.1.5.1.4 Connections between conductors and between conductors and other electrical equipment shall be made in such a way that safe and reliable contact is ensured.

4.1.5.1.5 All electrical equipment shall be installed in such a manner that the designed heat dissipation conditions are not impaired.

4.1.5.1.6 All electrical equipment likely to cause high temperatures or electric arcs shall be placed or guarded so as to minimize the risk of ignition of flammable materials. Where the temperature of any exposed parts of electrical equipment is likely to cause injury to persons, those parts shall be so located or guarded as to prevent accidental contact therewith.

4.1.5.1.7 Where necessary for safety purposes, suitable warning signs and/or notices shall be provided.

4.1.5.1.8 Where an installation is erected by using new materials, inventions or methods leading to deviations from the rules of this standard, the resulting degree of safety of the installation shall not be less than that obtained by compliance with this standard.

4.1.5.1.9 In the case of an addition or alteration to an existing installation, it shall be determined that the rating and condition of existing equipment, which will have to carry any additional load, is adequate for the altered circumstances. Furthermore, the earthing and bonding arrangements, if necessary for the protective measure applied for the safety of the addition or alteration, shall be adequate.

4.1.5.2 *Initial verification*

Electrical installations shall be verified before being

placed in service and after any important modification to confirm proper execution of the work in accordance with this standard.

4.1.5.3 *Periodic verification*

It is recommended that every electrical installation is subjected to periodic verification.

4.1.5.4 *Void*

4.1.5.5 *Assessment of general characteristics*

An assessment shall be made of the following characteristics of the installation in accordance with the clauses indicated:

a) the purposes for which the installation is intended to be used, its general structure and its supplies (**4.1.5.9**, **4.1.5.14** and **4.1.5.15**);
b) the external influences to which it is to be exposed (**4.1.5.11**);
c) the compatibility of its equipment (**4.1.5.12**); and
d) its maintainability (**4.1.5.13**).

Those characteristics shall be taken into account in the choice of methods of protection for safety (*see* **4.2** to **4.5**) and the selection and erection of equipment (*see* **5.1** to **5.5**).

4.1.5.6 *Purposes, supplies and structure*

4.1.5.6.1 *Maximum demand and diversity*

For economic and reliable design of an installation within thermal and voltage drop limits, a determination of maximum demand is essential. In determining the maximum demand of an installation, or part thereof, diversity may be taken into account.

4.1.5.7 *Void*

4.1.5.8 *Conductor arrangement and system earthing*

The following characteristics shall be assessed:

a) arrangements of current-carrying conductors under normal operating conditions; and
b) types of system earthing.

4.1.5.8.1 *Current-carrying conductors depending on kind of current*

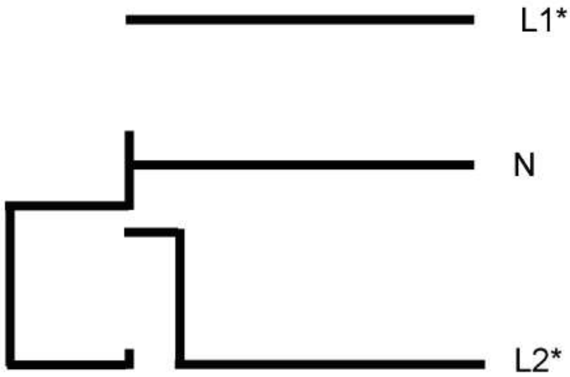
The following arrangements of current-carrying conductors under normal operating conditions are taken into account in this standard:

NOTE — The conductor arrangements described in this clause are not exhaustive. They are included as examples of typical arrangements.

a) Current carrying conductors in a.c. circuits (*see* Fig. 2 to Fig. 6).

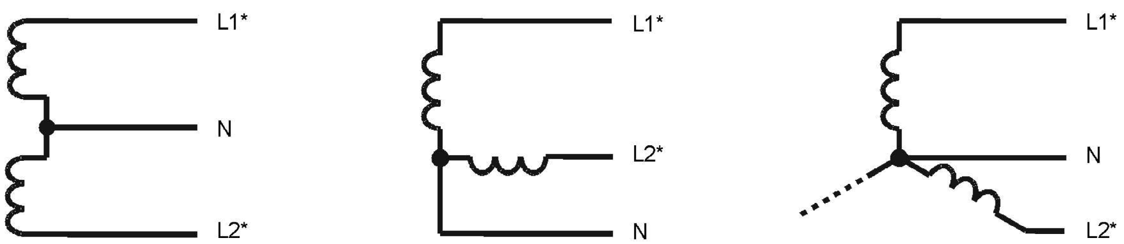
* Numbering of conductors optional

FIG. 2 SINGLE-PHASE 2-WIRE



Phase angle 0°
* Numbering of conductors optional

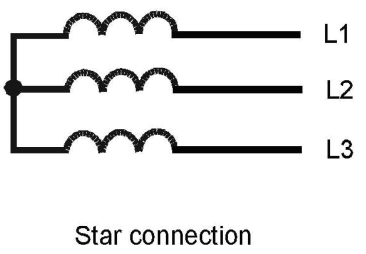
FIG. 3 SINGLE-PHASE 3-WIRE



Phase angle 180° Phase angle 90° Phase angle 120°

* Numbering of conductors optional

FIG. 4 TWO-PHASE 3-WIRE



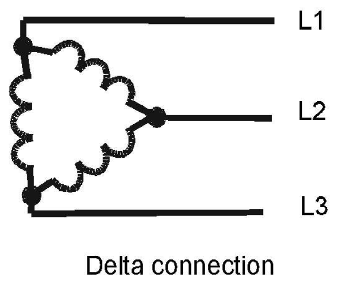


FIG. 5 THREE-PHASE 3-WIRE

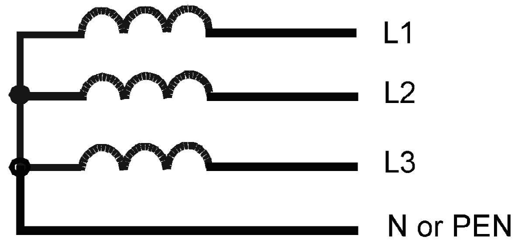


FIG. 6 THREE-PHASE 4-WIRE (*see* Note 3)

NOTES

1 In case of a single-phase 2-wire arrangement which is derived from a three-phase 4-wire arrangement, the two conductors are either two line conductors or a line conductor and a neutral conductor or a line conductor and a PEN conductor.

2 In installations with all loads connected between phases, the installation of the neutral conductor may not be necessary.

3 Three-phase, 4-wire with neutral conductor or PEN conductor. By definition, the PEN is not a live conductor but a conductor carrying an operating current.

b) Current-carrying conductors in d.c. circuits — *See* Fig. 7 and Fig. 8.

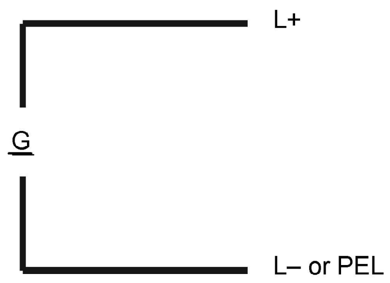


FIG. 7 2-WIRE

FIG. 8 3-WIRE

NOTE — PEL and PEM conductors are not live conductors although they carry operating current. Therefore, the designation 2-wire arrangement or 3-wire arrangement applies.

4.1.5.8.2 *Types of system earthing*

The following types of system earthing are taken into account in this standard.

NOTES

1 Figure 9 to Fig. 21 show examples of commonly used three-phase systems. Figure 22 to Fig. 26 show examples of commonly used d.c. systems.

2 The dotted lines indicate the parts of the system that are not covered by the scope of the standard, whereas the solid lines indicate the part that is covered by the standard.

3 For private systems, the source and/or the distribution system may be considered as part of the installation within the meaning of this standard. For this case, the figures may be completely shown in solid lines.

4 The codes used have the following meanings:

First letter — Relationship of the power system to earth:

T = direct connection of one point to earth; and

I = all live parts isolated from earth, or one point connected to earth through a high impedance.

Second letter — Relationship of the exposed-conductive-parts of the installation to earth:

T = direct electrical connection of exposed-conductive-parts to earth, independently of the earthing of any point of the power system; and

N = direct electrical connection of the exposed-conductive-parts to the earthed point of the power system (in a.c. systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a line conductor).

Subsequent letter(s) (*if any*)— Arrangement of neutral and protective conductors:

S = protective function provided by a conductor separate from the neutral conductor or from the earthed line (or, in a.c. systems, earthed phase) conductor.

C = neutral and protective functions combined in a single conductor (PEN conductor).

Explanation of symbols for Fig. 9 to Fig. 26 according to IS 12032 (all parts)	
	Neutral conductor (N); mid-point conductor (M)
	Protective conductor (PE)
	Combined protective and neutral conductor (PEN)

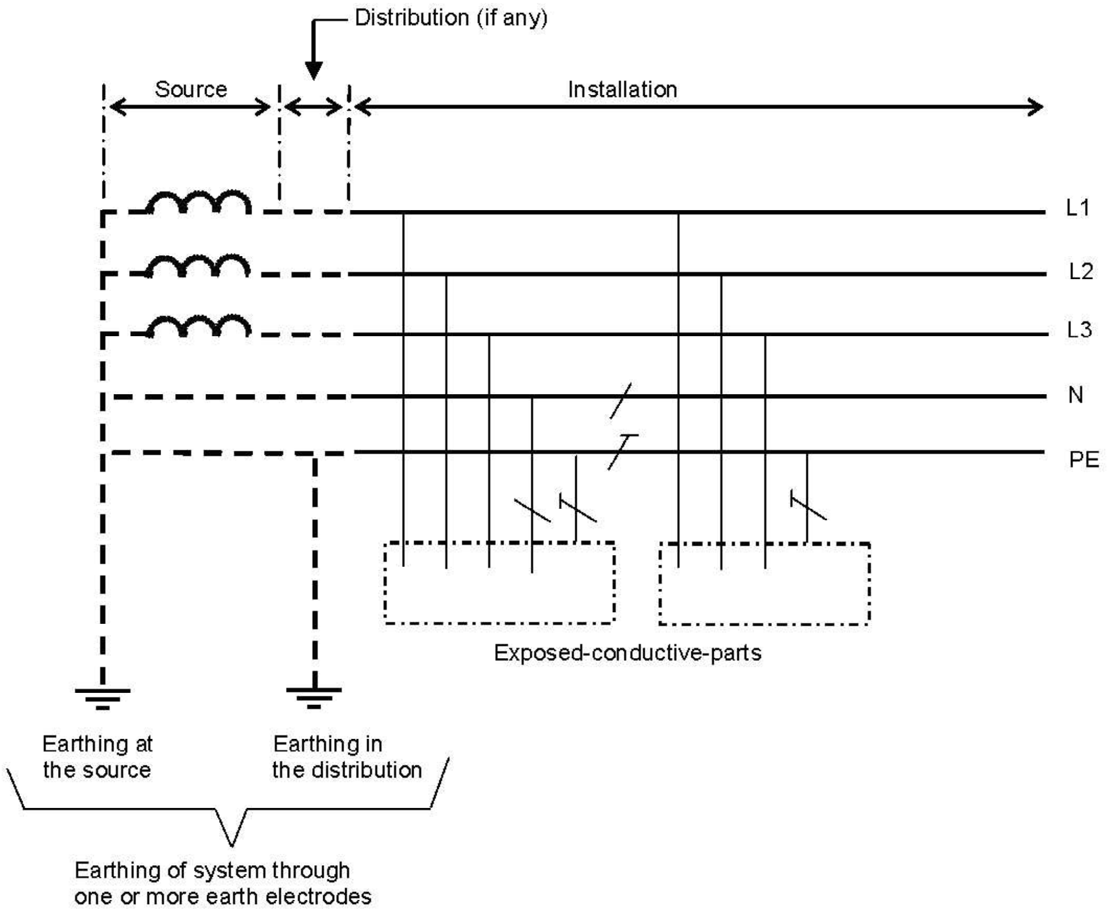
4.1.5.8.2.1 *TN systems*

a) *Single source systems*

TN power systems have one point directly earthed at the source, the exposed conductive parts of the installation being connected to that point by protective conductors. Three types of TN system are considered according to the arrangement of neutral and protective conductors, as follows:

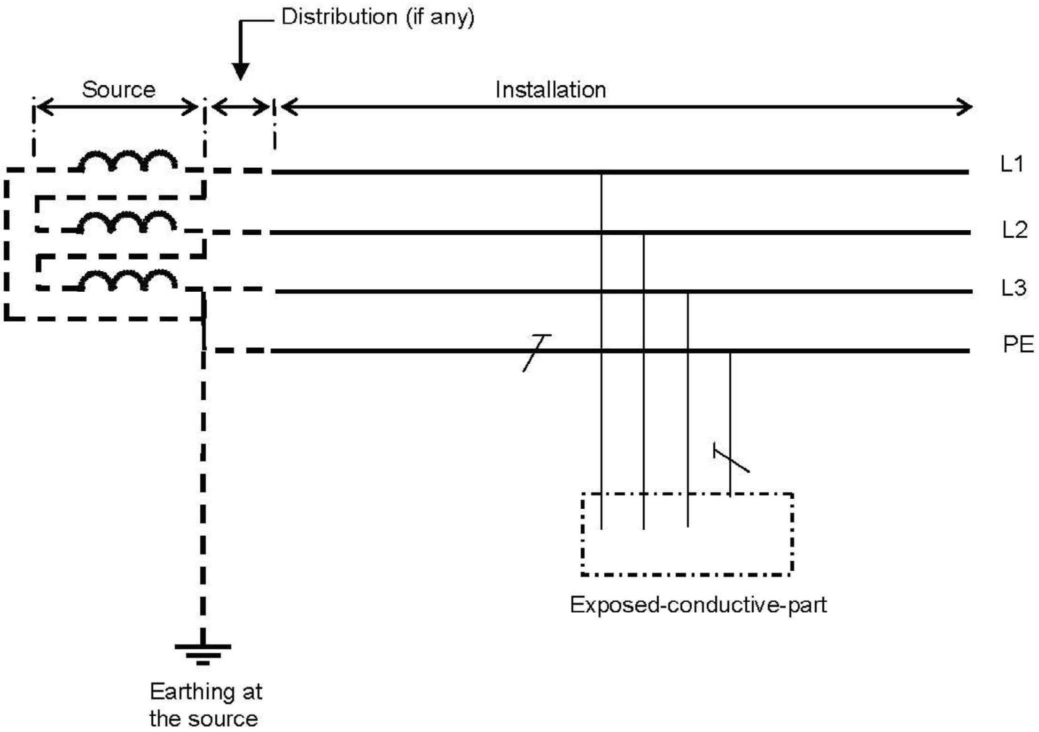
1) TN-S system in which, throughout the system, a separate protective conductor is used (*see* Fig. 9 to Fig. 11).

NOTE — For symbols, *see* explanation given in **4.1.5.8.2**.



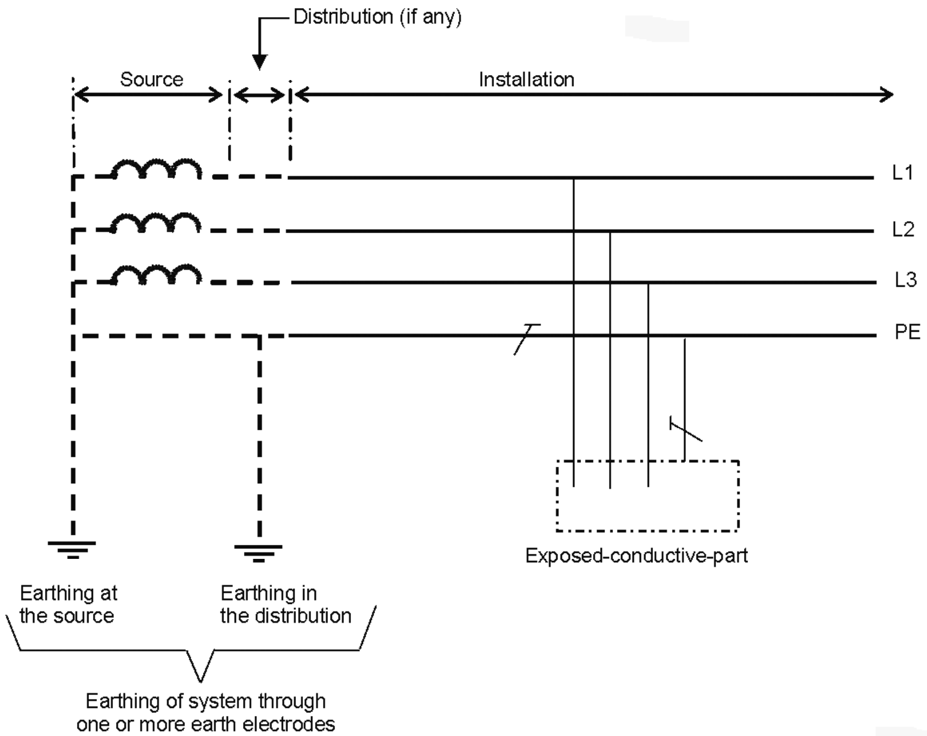
NOTE — Additional earthing of the PE in the installation must be provided.

FIG. 9 TN-S SYSTEM WITH SEPARATE NEUTRAL CONDUCTOR AND PROTECTIVE CONDUCTOR THROUGHOUT THE SYSTEM



NOTE — Additional earthing of the PE in the distribution and in the installation must be provided.

FIG. 10 TN-S SYSTEM WITH SEPARATE EARTHED LINE CONDUCTOR AND PROTECTIVE CONDUCTOR THROUGHOUT THE SYSTEM

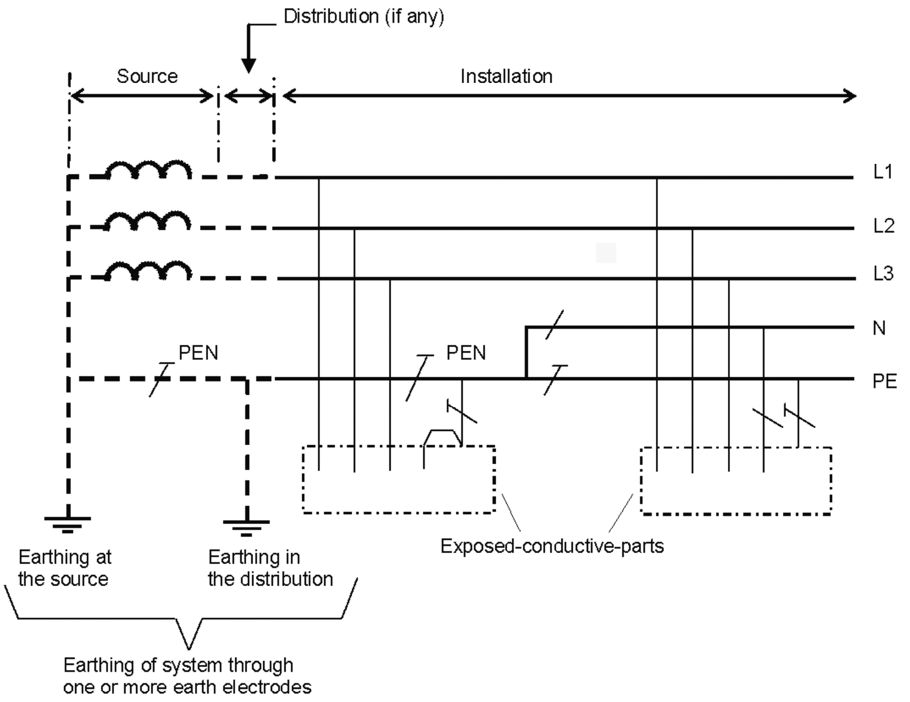


NOTE — Additional earthing of the PE in the installation must be provided.

FIG. 11 TN-S SYSTEM WITH EARTHED PROTECTIVE CONDUCTOR AND NO DISTRIBUTED NEUTRAL CONDUCTOR THROUGHOUT THE SYSTEM

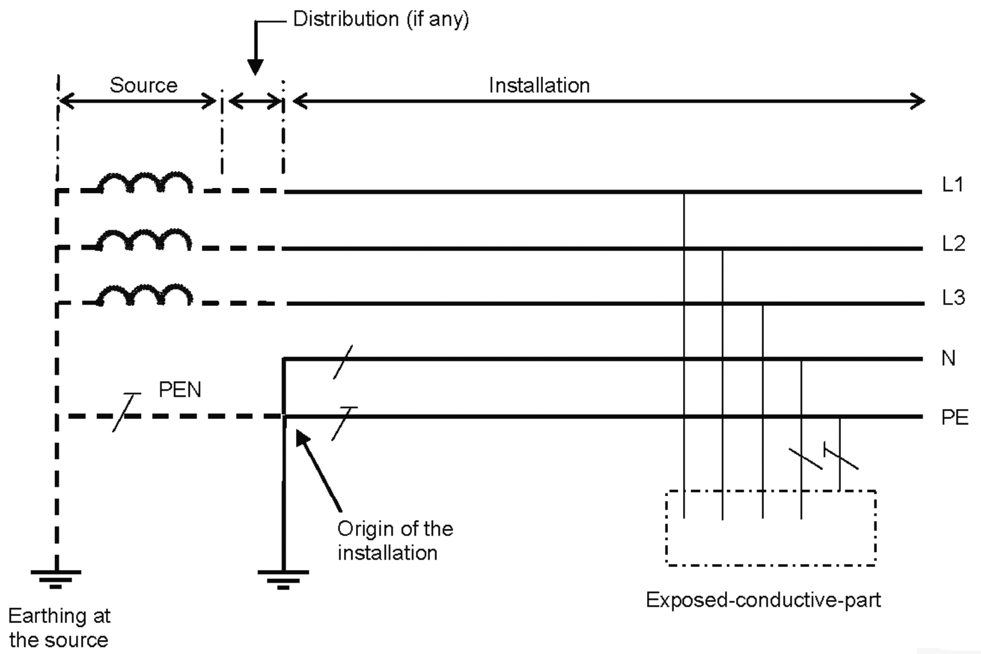
2) TN-C-S system in which neutral and protective conductor functions are combined in a single conductor in a part of the system (*see* Fig. 12 to Fig. 14).

NOTE — For symbols, *see* explanation given in **4.1.3.2**.



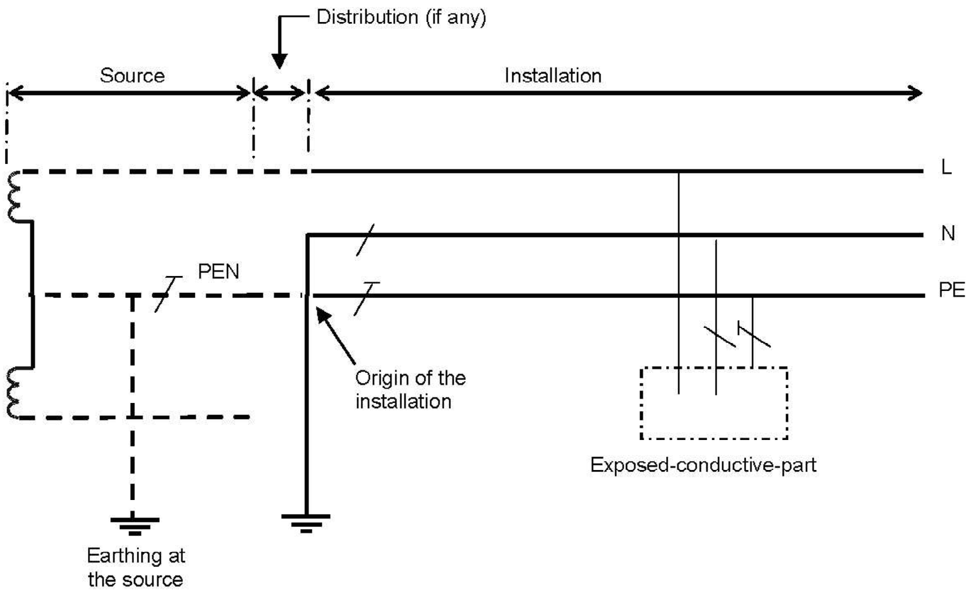
NOTE — Additional earthing of the PEN or PE in the installation must be provided.

FIG. 12 TN-C-S SYSTEM 3-PHASE, 4-WIRE, WHERE PEN IS SEPARATED INTO PE AND N ELSEWHERE IN THE INSTALLATION



NOTE — Additional earthing of the PEN in the distribution and of the PE in the installation must be provided.

FIG. 13 TN-C-S SYSTEM 3-PHASE, 4-WIRE, WHERE PEN IS SEPARATED INTO PE AND N AT THE ORIGIN OF THE INSTALLATION

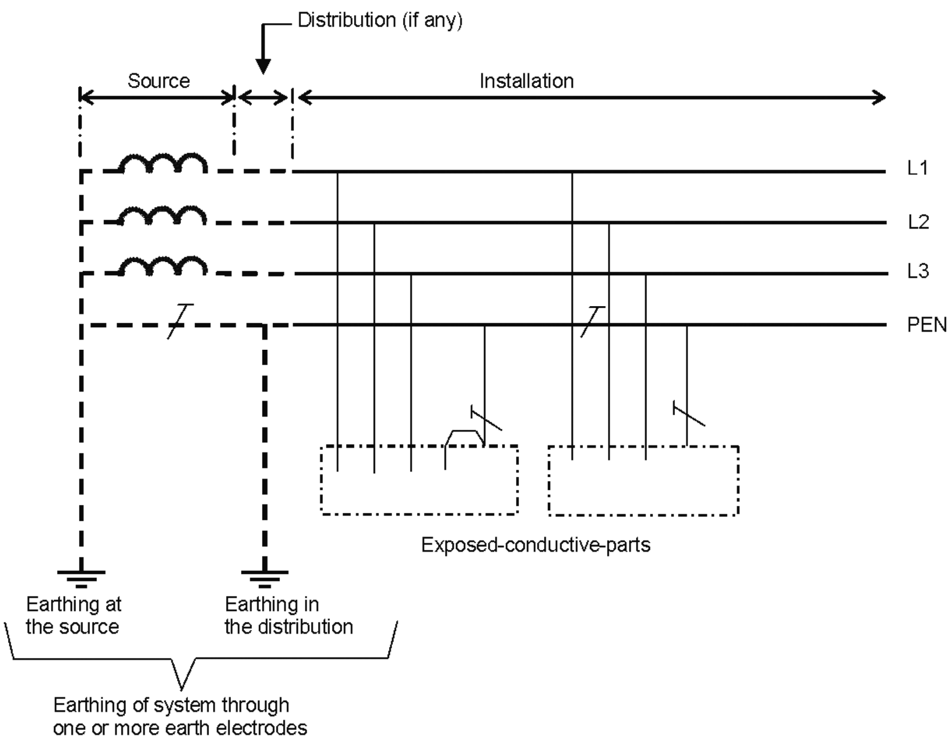


NOTE — Additional earthing of the PEN in the distribution and of the PE in the installation must be provided.

FIG. 14 TN-C-S SYSTEM SINGLE-PHASE, 2-WIRE, WHERE THE PEN IS SEPARATED INTO PE AND N AT THE ORIGIN OF THE INSTALLATION

3) TN-C system in which neutral and protective conductor functions are combined in a single conductor throughout the system (*see* Fig. 15).

NOTE — For symbols, *see* explanation given in **4.1.5.8.2**.



NOTE — Additional earthing of the PEN in the installation must be provided.

FIG. 15 TN-C WITH NEUTRAL AND PROTECTIVE CONDUCTOR FUNCTIONS COMBINED IN A SINGLE CONDUCTOR THROUGHOUT THE SYSTEM

b) *Multiple source systems*

NOTE — The multiple source system is shown for the TN system with the unique aim of providing EMC. The multiple source system is not shown for IT and TT systems because these systems are generally compatible with regard to EMC.

In the case of an inappropriate design of an installation forming part of a TN system with multiple sources some of the operating current may flow through unintended paths. These currents may cause

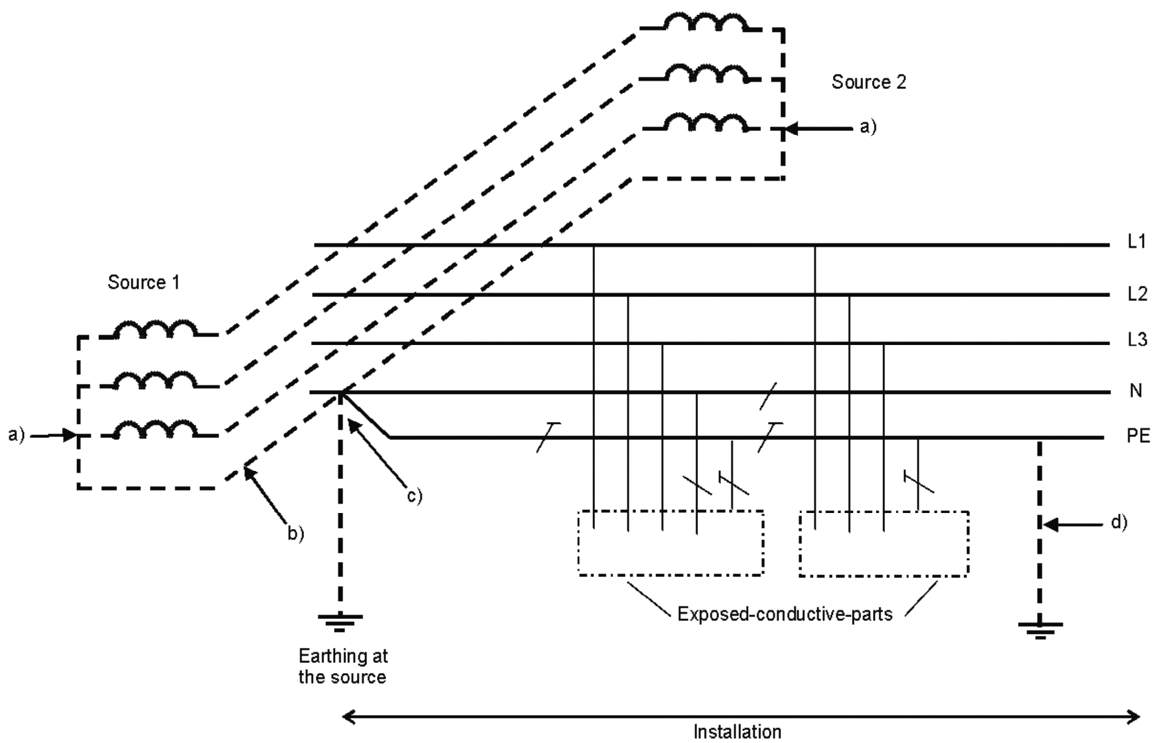
a) fire;
b) corrosion; and
c) electromagnetic interference.

The system shown in Fig. 16 is a system where minor partial operating currents flow as currents through unintended paths. The essential design rules shown in Fig. 16 from *a*) to *d*) are given in the legend below Fig. 16.

The marking of the PE conductor shall be in accordance with IEC 60446.

Any extension of the system shall be taken into account with regard to the proper functioning of the protective measures.

In industrial plants with only 2-phase loads and 3-phase loads between line conductors, it is not necessary to provide a neutral conductor (*see* Fig. 17). In this case, the protective conductor should have multiple connections to earth.



Key

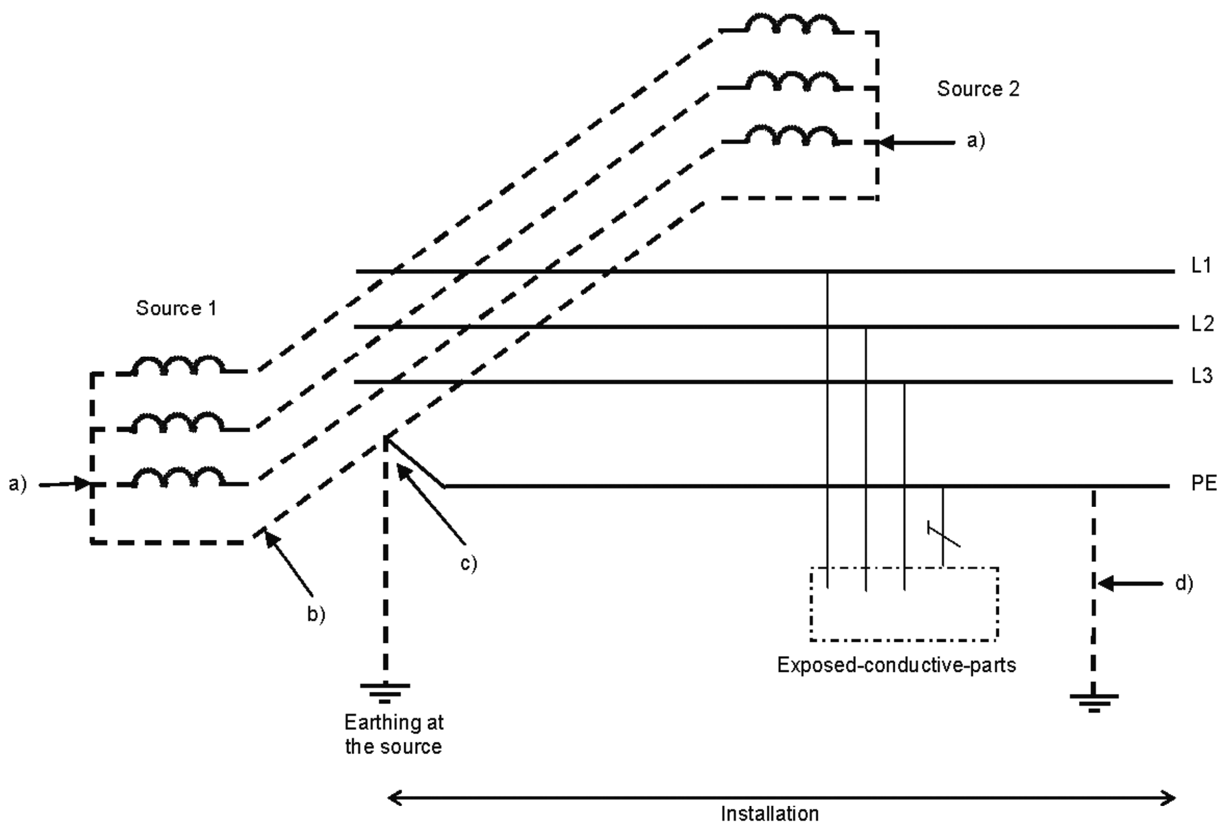
a) — No direct connection from either the transformer neutral point or the generator star point to earth is permitted.

b) — The interconnection conductor between either the neutral points of the transformers or the generator star points shall be insulated. The function of this conductor is like a PEN; however, it shall not be connected to current-using equipment.

c) — Only one connection between the interconnected neutral points of the sources and the PE shall be provided. This connection shall be located inside the main switchgear assembly.

d) — Additional earthing of the PE in the installation must be provided.

FIG. 16 TN-C-S MULTIPLE SOURCE SYSTEM WITH SEPARATE PROTECTIVE CONDUCTOR AND NEUTRAL CONDUCTOR TO CURRENT USING EQUIPMENT



Key

a) — No direct connection from either the transformer neutral point or the generator star point to earth is permitted.

b) — The interconnection conductor between either the neutral points of the transformers or the generator star points shall be insulated. The function of this conductor is like a PEN; however, it shall not be connectedto current-using equipment.

c) — Only one connection between the interconnected neutral points of the sources and the PE shall be provided. This connection shall be located inside the main switchgear assembly.

d) — Additional earthing of the PE in the installation must be provided.

FIG. 17 TN-C-S MULTIPLE SOURCE SYSTEM WITH PROTECTIVE CONDUCTOR AND NO NEUTRAL CONDUCTOR THROUGHOUT THE SYSTEM FOR 2- OR 3-PHASE LOAD

4.1.5.8.2.2 *TT system*

The TT system has only one point directly earthed and the exposed-conductive-parts of the installation are connected to earth electrodes electrically independent of the earth electrode of the supply system (*see* Fig. 18 and Fig. 19).

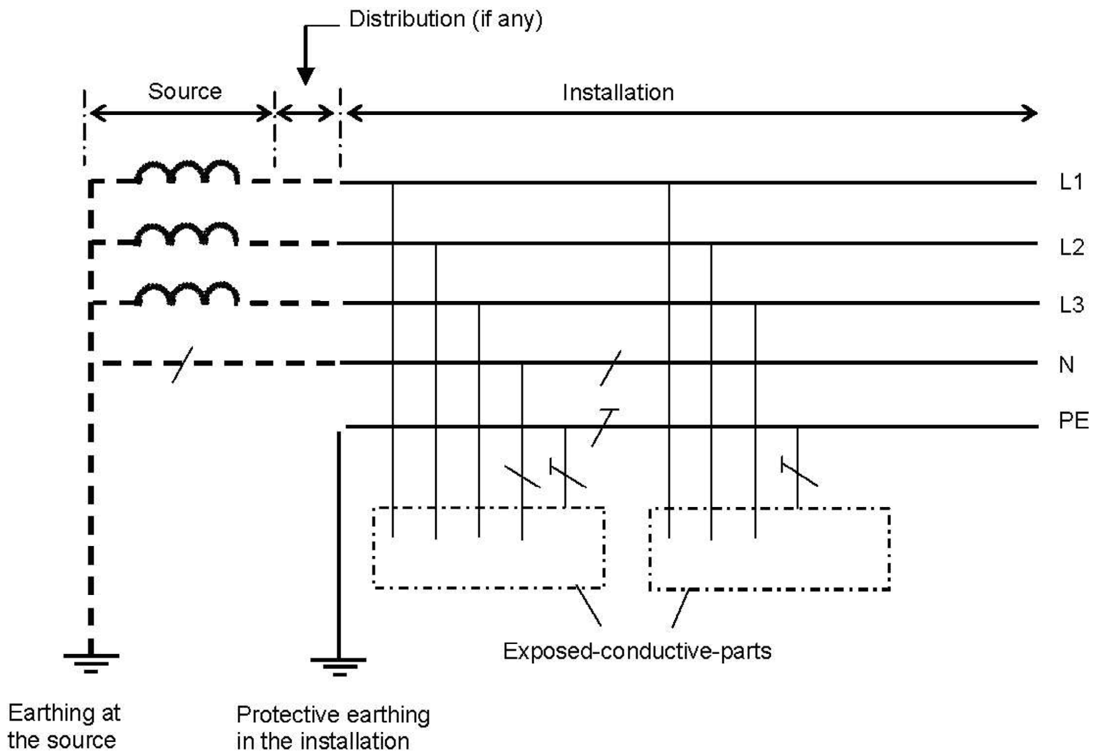
4.1.5.8.2.3 *IT system*

The IT power system has all live parts isolated from earth or one point connected to earth through an impedance. The exposed-conductive-parts of the electrical installation are earthed independently or collectively or to the earthing of the system according to **4.2.11.6** (*see* Fig. 20 and Fig. 21).

4.1.5.8.2.4 *d.c. systems*

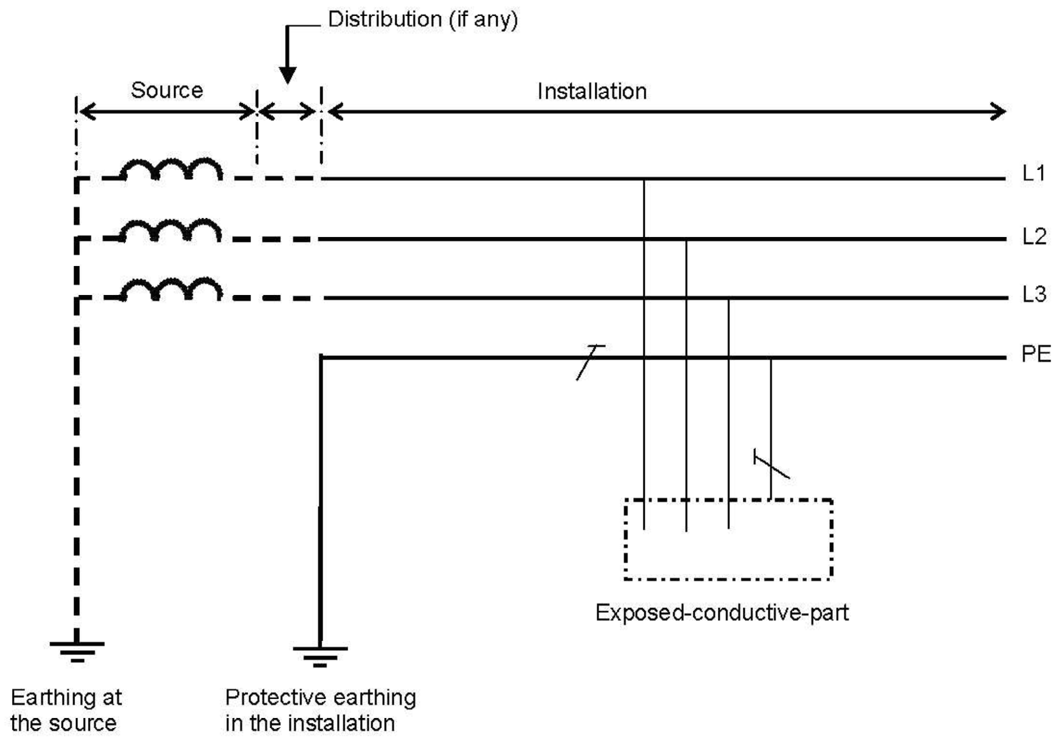
Type of system earthing for direct current (d.c.) systems.

Where the following Fig. 22 to Fig. 26 show earthing of a specific pole of a two-wire d.c. system, the decision whether to earth the positive or the negative pole shall be based upon operational circumstances or other considerations, for example, avoidance of corrosion effects on line conductors and earthing arrangements.



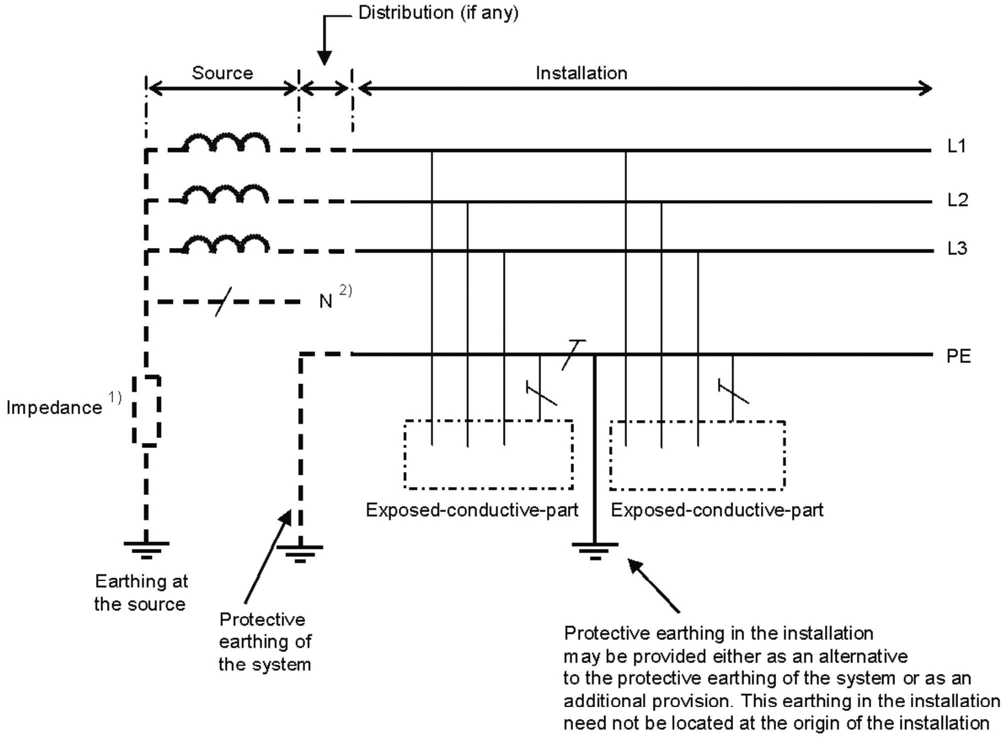
NOTE — Additional earthing of the PE in the installation must be provided.

FIG. 18 TT SYSTEM WITH SEPARATE NEUTRAL CONDUCTOR AND PROTECTIVE CONDUCTOR THROUGHOUT THE INSTALLATION



NOTE — Additional earthing of the PE in the installation must be provided.

FIG. 19 TT SYSTEM WITH EARTHED PROTECTIVE AND NO DISTRIBUTED NEUTRAL CONDUCTOR THROUGHOUT THE INSTALLATION

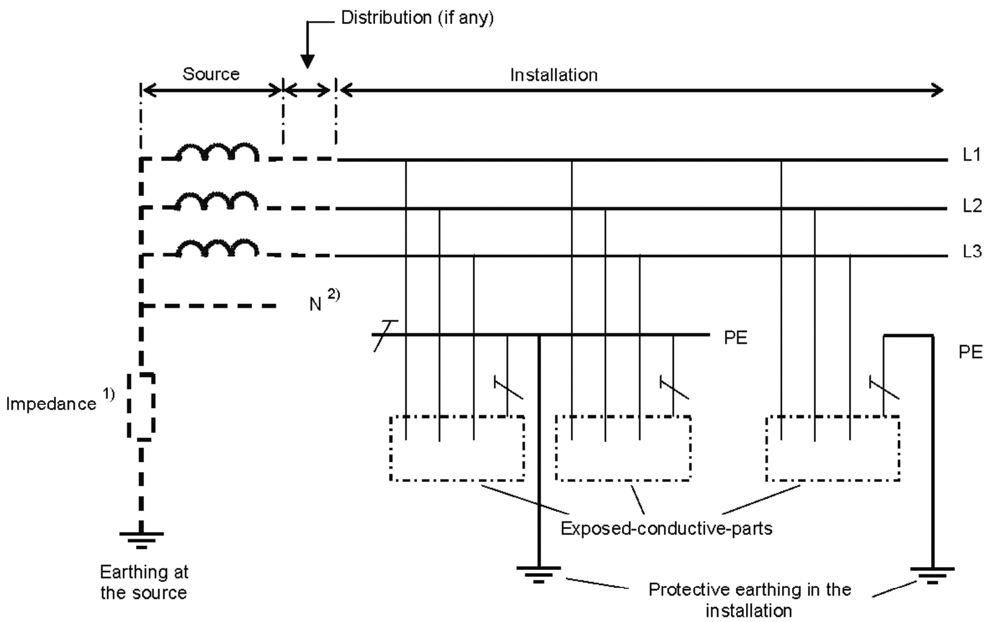


NOTE — Additional earthing of the PE in the installation must be provided.

a) The system may be connected to earth via a sufficiently high impedance. This connection may be made, for example, at the neutral point, artificial neutral point, or a line conductor.

b) The neutral conductor may or may not be distributed.

FIG. 20 IT SYSTEM WITH ALL EXPOSED-CONDUCTIVE-PARTS INTERCONNECTED BY A PROTECTIVE CONDUCTOR WHICH IS COLLECTIVELY EARTHED



NOTE — Additional earthing of the PE in the installation must be provided.

a) The system may be connected to earth via a sufficiently high impedance.

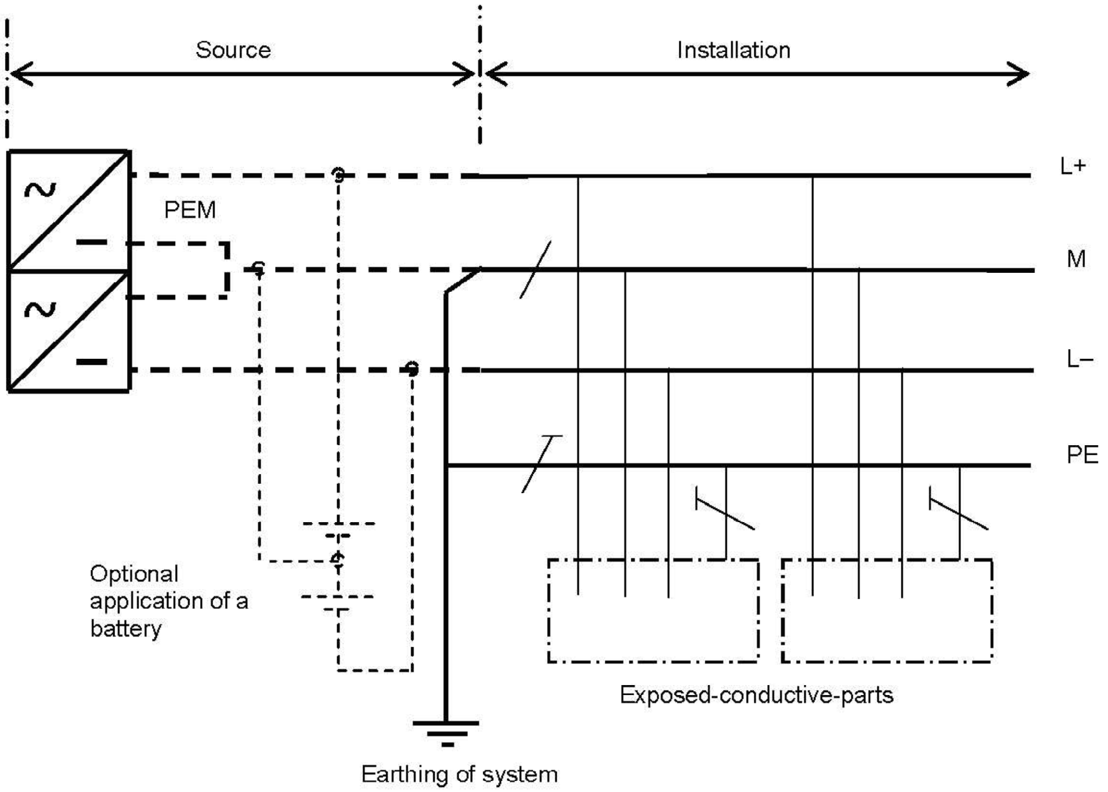
b) The neutral conductor may or may not be distributed.

FIG. 21 IT SYSTEM WITH EXPOSED-CONDUCTIVE-PARTS EARTHED IN GROUPS OR INDIVIDUALLY

4.1.5.8.2.4.1 *TN-S-system*

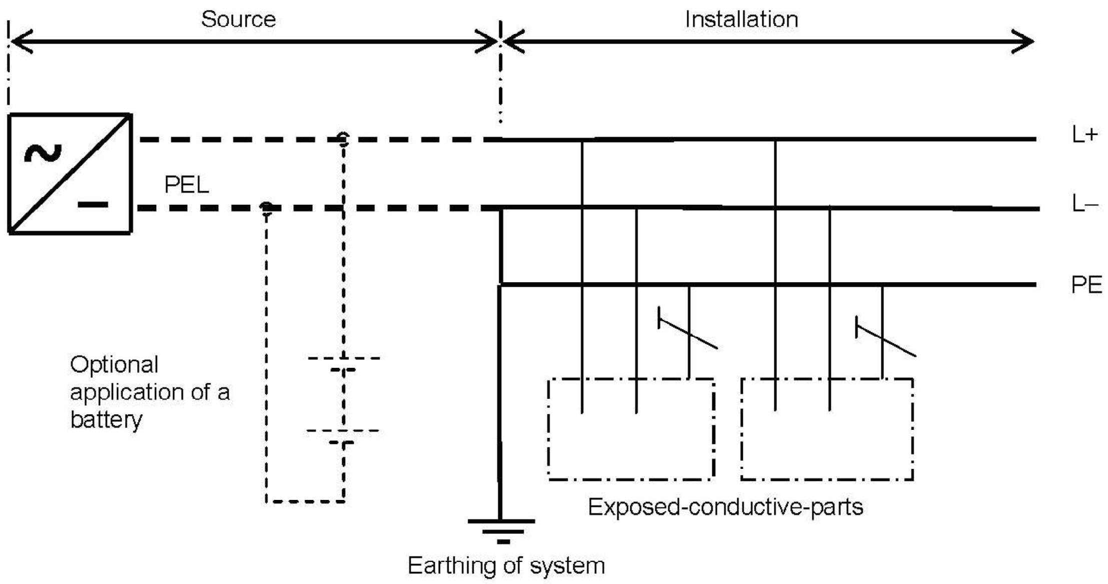
The earthed line conductor for example L– in type (a) or the earthed mid-point conductor M in type (b) is separated from the protective conductor throughout the installation.

Type a)



NOTE — Additional earthing of the PE in the installation must be provided.

Type b)



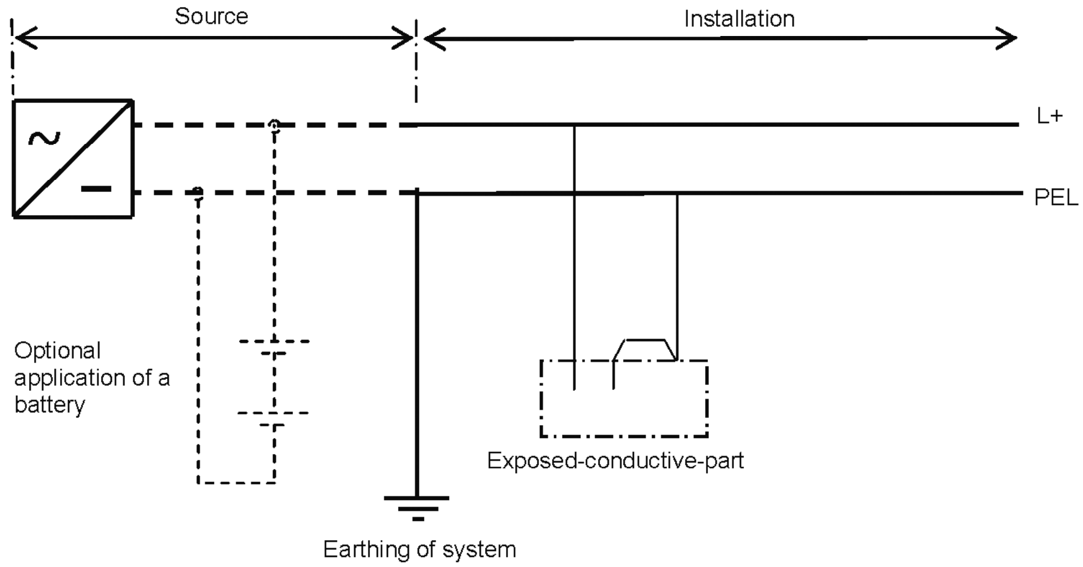
NOTE — Additional earthing of the PE in the installation must be provided.

FIG. 22 TN-S d.c. SYSTEM

4.1.5.8.2.4.2 *TN-C-system*

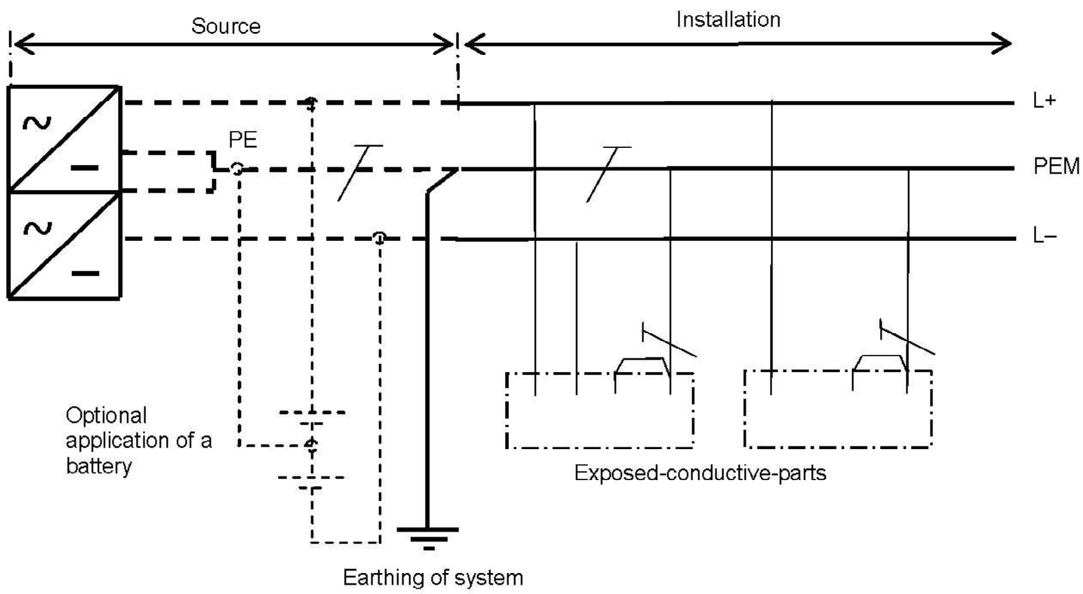
The functions of the earthed line conductor for example L– and of the protective conductor are in type (a) combined in one single conductor PEL throughout the installation, or the earthed mid-point conductor M and the protective conductor are combined in type (b) in one single conductor PEM throughout the installation.

Type a)



NOTE — Additional earthing of the PEL in the installation must be provided.

Type b)



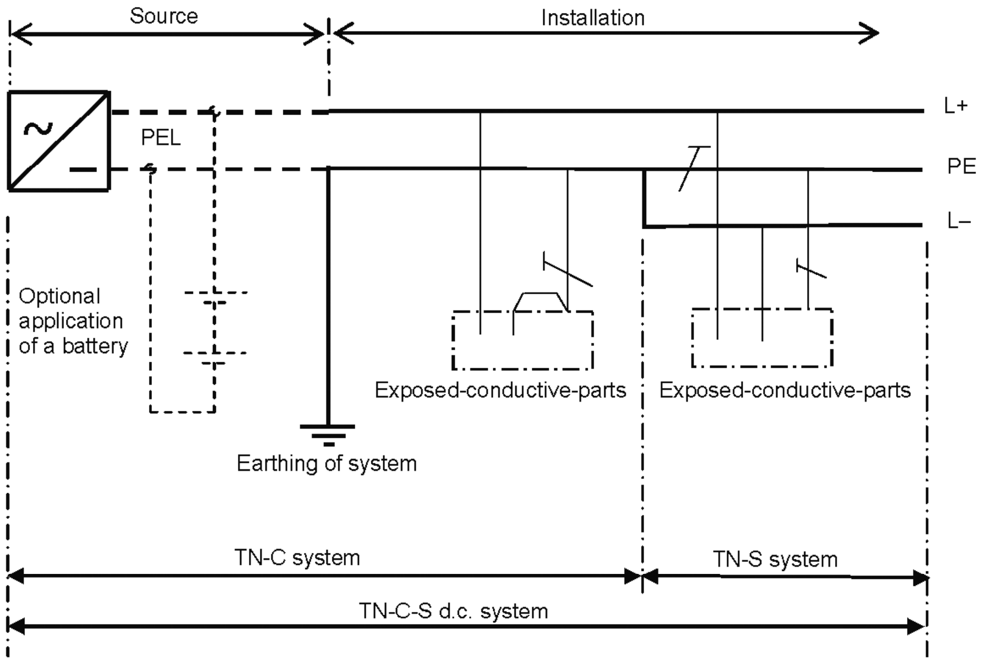
NOTE — Additional earthing of the PEM in the installation must be provided.

FIG. 23 TN-C d.c. SYSTEM

4.1.5.8.2.4.3 *TN-C-S-system*

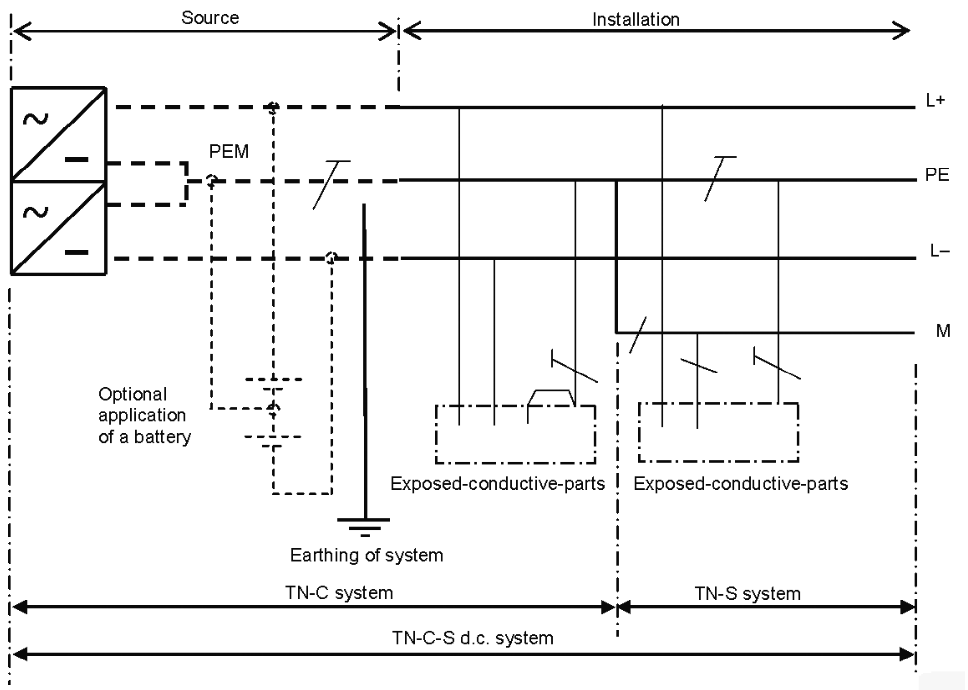
The functions of the earthed line conductor for example L– in type (a) and of the protective conductor are combined in one single conductor PEL in a part of the installation, or the earthed mid-wire conductor M in type (b) and the protective conductor are combined in one single conductor PEM in a part of the installation.

Type a)



NOTE — Additional earthing of the PE in the installation must be provided.

Type b)

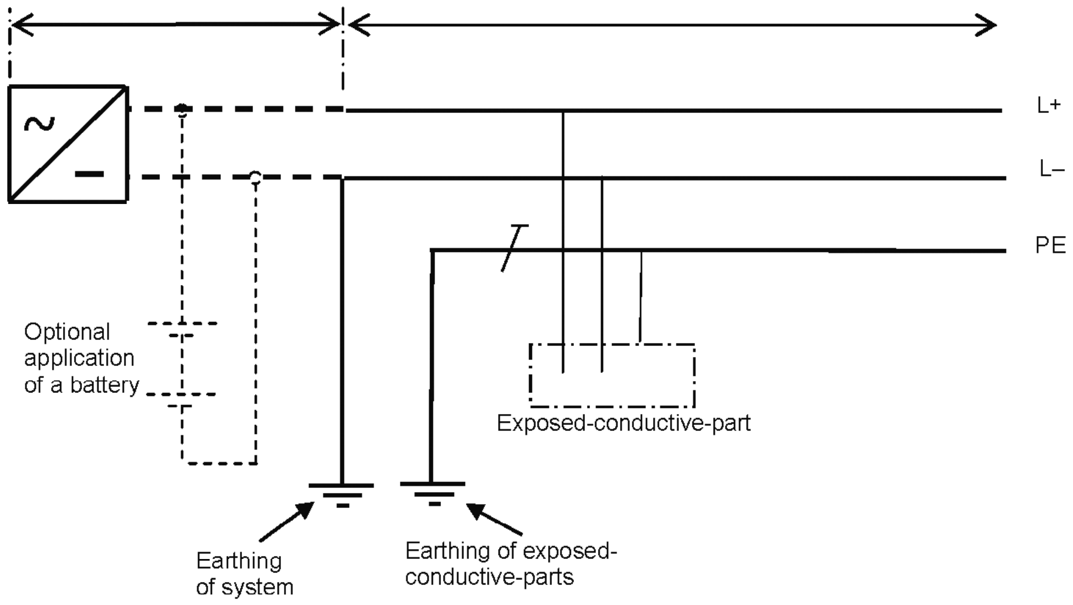


NOTE — Additional earthing of the PE in the installation must be provided.

FIG. 24 TN-C-S d.c. SYSTEM

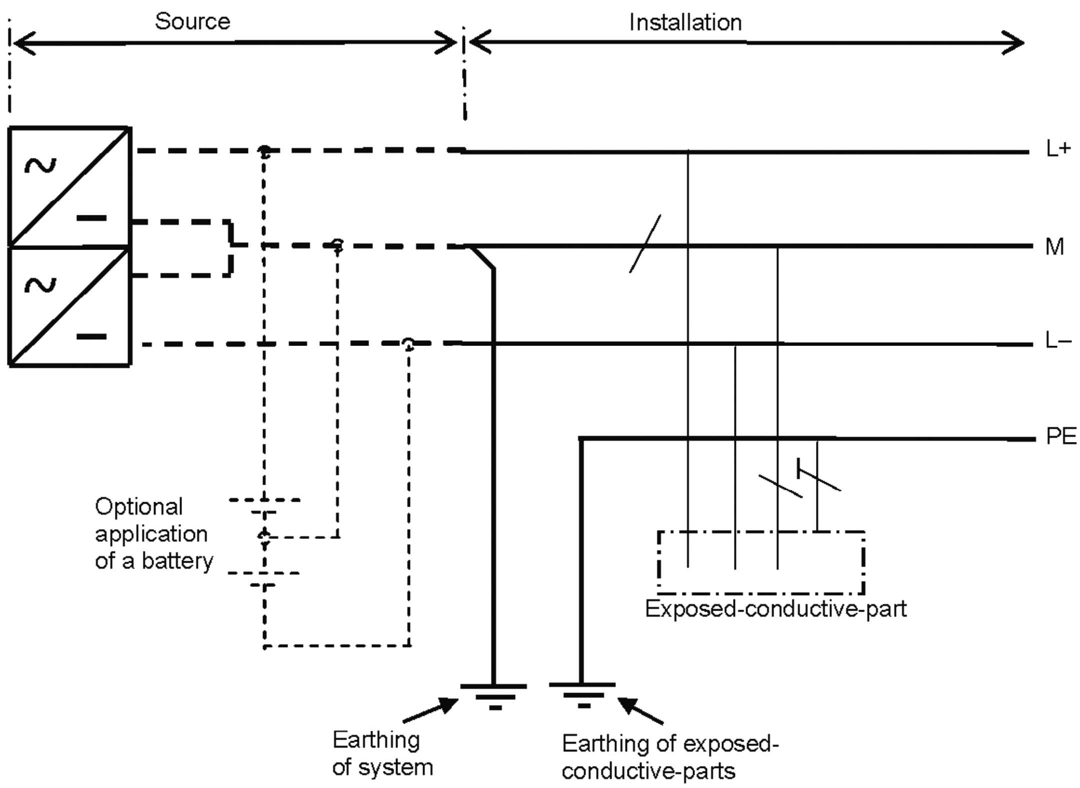
4.1.5.8.2.4.4 *TT-system*

Type a)



NOTE — Additional earthing of the PE in the installation must be provided.

Type b)

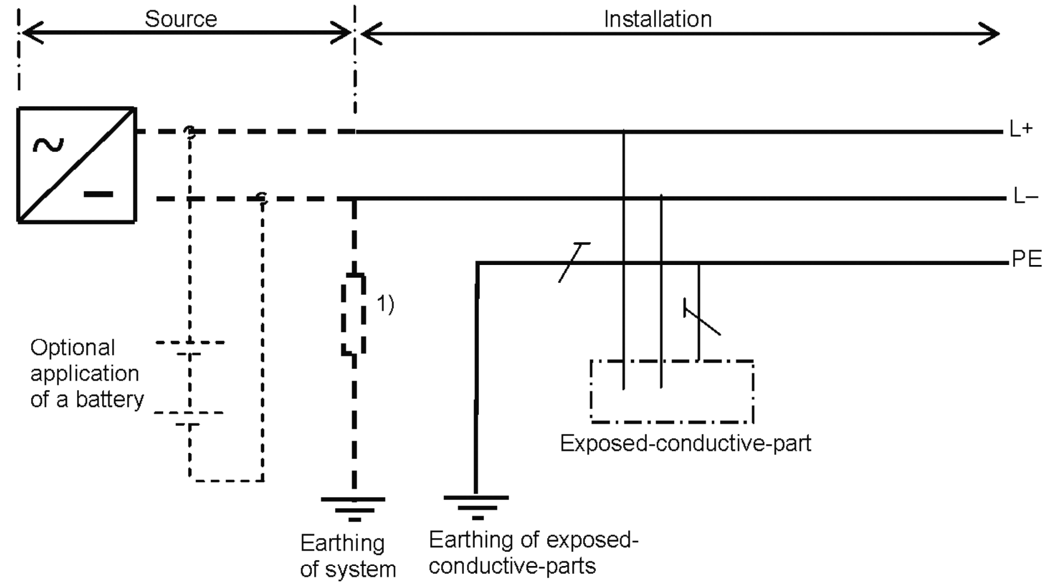


NOTE — Additional earthing of the PE in the installation must be provided.

FIG. 25 TT d.c. SYSTEM

4.1.5.8.2.4.5 *IT-system*

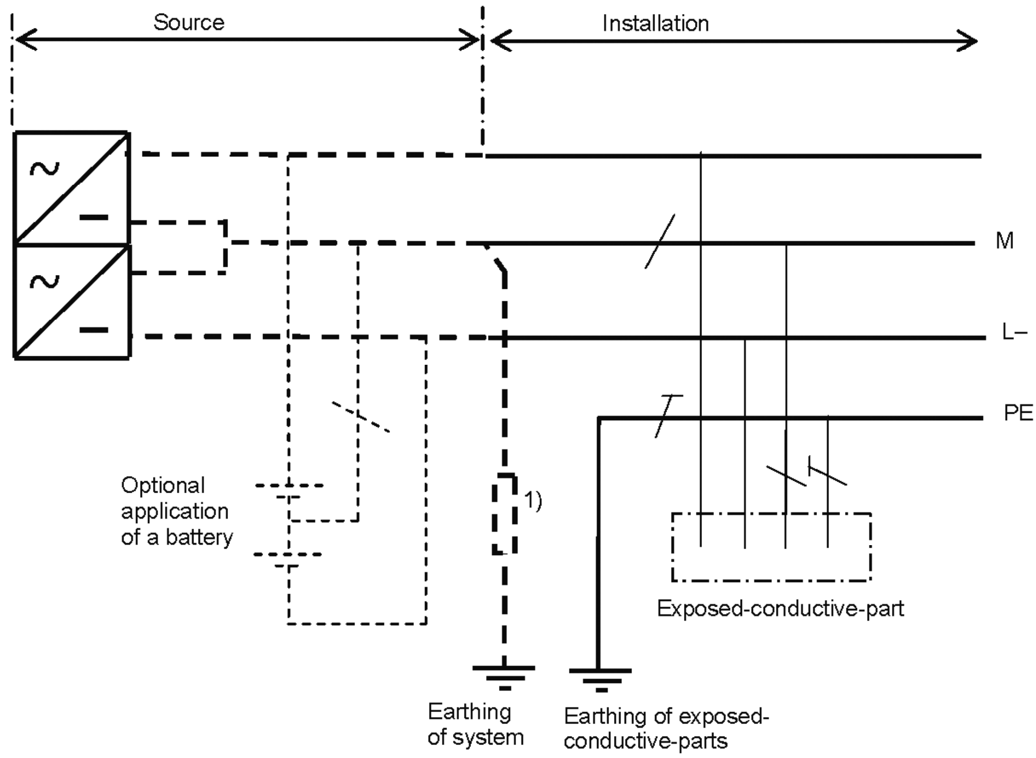
Type a)



1) — The system may be connected to earth via a sufficiently high impedance.

NOTE — Additional earthing of the PE in the installation must be provided.

Type b)



1) — The system may be connected to earth via a sufficiently high impedance.

NOTE — Additional earthing of the PE in the installation must be provided.

FIG. 26 IT d.c. SYSTEM

4.1.5.9 *Supplies*

4.1.5.9.1 *General*

4.1.5.9.1.1 The following characteristics of the supply or supplies, from whatever source, and the normal range of those characteristics where appropriate, shall be determined by calculation, measurement, enquiry or inspection:

a) the nominal voltage(s);
b) the nature of the current and frequency;
c) the prospective short-circuit current at the origin of the installation;
d) the earth fault loop impedance of that part of the system external to the installation;
e) the suitability for the requirements of the installation, including the maximum demand; and
f) the type and rating of the overcurrent protective device acting at the origin of the installation.

These characteristics shall be ascertained for an external supply and shall be determined for a private source. These requirements are equally applicable to main supplies and to safety services and standby supplies.

4.1.5.9.2 *Supplies for safety services and standby systems*

Where the provision of safety services is required, for example, by the authorities concerned with fire precautions and other conditions for emergency evacuation of the premises, and/or where the provision of standby supplies is required by the person specifying the installation, the characteristics of the sources of supply for safety services and/or standby systems shall be separately assessed. Such supplies shall have adequate capacity, reliability and rating and appropriate change-over time for the operation specified.

For further requirements for supplies for safety services, *see* **4.1.5.14** hereafter and **5.6**. For standby systems, there are no particular requirements in this standard.

4.1.5.10 *Division of installation*

4.1.5.10.1 Every installation shall be divided into circuits, as necessary, to

a) avoid danger and minimize inconvenience in the event of a fault;
b) facilitate safe inspection, testing and maintenance (*see also* **5.3**);
c) take account of danger that may arise from the failure of a single circuit such as a lighting circuit;
d) reduce the possibility of unwanted tripping of RCDs due to excessive PE conductor currents not due to a fault;
e) mitigate the effects of EMI;
f) prevent the indirect energizing of a circuit intended to be isolated.

4.1.5.10.2 Separate distribution circuits shall be provided for parts of the installation which need to be separately controlled, in such a way that those circuits are not affected by the failure of other circuits.

4.1.5.11 *Classification of external influences*

NOTE — This clause has been transferred to **5.1.2.2**.

4.1.5.12 *Compatibility*

4.1.5.12.1 *Compatibility of characteristics*

An assessment shall be made of any characteristics of equipment likely to have harmful effects upon other electrical equipment or other services or likely to impair the supply, for example, for coordination with concerned parties. Those characteristics include, for example:

a) transient overvoltages;
b) undervoltage;
c) unbalanced loads;
d) rapidly fluctuating loads;
e) starting currents;
f) harmonic currents;
g) d.c. feedback;
h) high-frequency oscillations;
j) earth leakage currents;
k) necessity for additional connections to earth; and
m) excessive PE conductor currents not due to a fault.

4.1.5.12.2 *Electromagnetic compatibility*

All electrical equipment shall meet the appropriate electromagnetic compatibility (EMC) requirements, and shall be in accordance with the relevant EMC standards.

Consideration shall be given by the planner and designer of the electrical installations to measures reducing the effect of induced voltage disturbances and electromagnetic interferences (EMI).

Measures are given in **4.5**.

4.1.5.13 *Maintainability*

An assessment shall be made of the frequency and quality of maintenance, the installation can reasonably be expected to receive during its intended life. Where an authority is responsible for the operation of the installation, that authority shall be consulted. Those characteristics are to be taken into account in applying

the requirements of **4** to **6** so that, having regard to the frequency and quality of maintenance expected:

a) any periodic inspection and testing, maintenance and repairs likely to be necessary during the intended life can be readily and safely carried out;
b) the effectiveness of the protective measures for safety during the intended life shall remain, and
c) the reliability of equipment for proper functioning of the installation is appropriate to the intended life.

4.1.5.14 *Safety services*

4.1.5.14.1 *General*

NOTES

1 The need for safety services and their nature are frequently regulated by statutoryauthorities whose requirementshave to be observed.

2 Examples of safety services are: emergency escape lighting, fire alarm systems, installations for fire pumps, firebrigade lifts, smoke and heat extraction equipment.

The following sources for safety services are recognized:

a) storage batteries;
b) primary cells;
c) generator sets independent of the normal supply; and
d) a separate feeder of the supply network effectively independent of the normal feeder (*see* **5.6.4**).

4.1.5.14.2 *Classification*

A safety service is either:

– a non-automatic supply, the starting of which is initiated by an operator, or
– an automatic-supply, the starting of which is independent of an operator.

An automatic supply is classified as follows according to change-over time:

a) *no-break*: an automatic supply which can ensure a continuous supply within specified conditions during the period of transition, for example as regards variations in voltage and frequency;
b) *very short break*: an automatic supply available within 0.15 s;
c) *short break*: an automatic supply available within 0.5 s;
d) *medium break*: an automatic supply available within 15 s; and
e) *long break*: an automatic supply available in more than 15 s.

4.1.5.15 *Continuity of service*

An assessment shall be made for each circuit of any need for continuity of service considered necessary during the intended life of the installation. The following characteristics should be considered:

a) selection of the system earthing,
b) selection of the protective device in order to achieve discrimination,
c) number of circuits,
d) multiple power supplies, and;
e) use of monitoring devices.

4.2 Protection for Safety—Protection against Electric Shock

This clause deals with protection against electric shock as applied to electrical installations. It is based on IEC 61140 which is a basic safety standard that applies to the protection of persons and livestock. IEC 61140 is intended to give fundamental principles and requirements that are common to electrical installations and equipment or are necessary for their co-ordination.

The fundamental rule of protection against electric shock, according to IEC 61140, is that hazardous live parts must not be accessible and accessible conductive parts must not be hazardous live, neither under normal conditions nor under single fault conditions.

The protection under normal conditions is provided by basic protective provisions and protection under single fault conditions is provided by fault protective provisions. Alternatively, protection against electric shock is provided by an enhanced protective provision, which provides protection under normal conditions and under single fault conditions.

4.2.1 In this standard the following specification of voltages is intended unless otherwise stated:

a) a.c. voltages are r.m.s.; and
b) d.c. voltages are ripple-free.

Ripple-free is conventionally defined as an r.m.s. ripple voltage of not more than 10 percent of the d.c. component.

4.2.2 A protective measure shall consist of:

a) an appropriate combination of a provision for basic protection and an independent provision for fault protection, or
b) an enhanced protective provision which provides both basic protection and fault protection.

Additional protection is specified as part of a protective measure under certain conditions of external influences and in certain special locations (*see* IEC 60364-7).

NOTES

1 For special applications, protective measures which do not follow this concept are permitted (*see* **4.2.6** and **4.2.7**).

2 An example of an enhanced protective measure is reinforced insulation.

4.2.3 In each part of an installation one or more protective measures shall be applied, taking into account of the conditions of external influence.

The following protective measures generally are permitted:

a) automatic disconnection of supply (**4.2.11**),
b) double or reinforced insulation (**4.2.12**),
c) electrical separation for the supply of one item of current-using equipment (**4.2.13**), and
d) extra-low-voltage (SELV and PELV) (**4.2.14**).

4.2.4 The protective measures applied in the installation shall be considered in the selection and erection of equipment.

For particular installations *see* **4.2.5** to **4.2.10**.

NOTE — In electrical installations the most commonly used protective measure is automatic disconnection of supply.

4.2.5 For special installations or locations, the particular protective measures given in IEC 60364-7 shall be applied.

4.2.6 The protective measures, specified in Annex B, that is., the use of obstacles and placing out of reach, shall only be used in installations accessible to:

a) skilled or instructed persons, or
b) persons under the supervision of skilled or instructed persons.

4.2.7 The protective measures, specified in Annex C, that is,

a) non-conducting location,
b) earth-free local equipotential bonding, and
c) electrical separation for the supply of more than one item of current-using equipment,

may be applied only when the installation is under the supervision of skilled or instructed persons so that unauthorized changes cannot be made.

4.2.8 If certain conditions of a protective measure cannot be met, supplementary provisions shall be applied so that the protective provisions together achieve the same degree of safety.

NOTE —An example of the application of this rule is given in **4.2.11.7**.

4.2.9 Different protective measures applied to the same installation or part of an installation or within equipment shall have no influence on each other such that failure of one protective measure could impair the other protective measures.

4.2.10 The provision for fault protection (protection against indirect contact) may be omitted for the following equipment:

a) metal supports of overhead line insulators which are attached to the building and are placed out of arm's reach;
b) steel reinforced concrete poles of overhead lines in which the steel reinforcement is not accessible;
c) exposed conductive parts which, owing to their reduced dimensions (approximately 50 mm × 50 mm) or their disposition cannot be gripped or come into significant contact with a part of the human body and provided that connection with a protective conductor could only be made with difficulty or would be unreliable; and

   NOTE —This exemption applies, for example, to bolts, rivets, nameplates and cable clips.
d) metal tubes or other metal enclosures protecting equipment in accordance with **4.2.12**.

4.2.11 *Protective Measure: Automatic Disconnection of Supply*

4.2.11.1 *General*

Automatic disconnection of supply is a protective measure in which:

a) basic protection is provided by basic insulation of live parts or by barriers or enclosures, in accordance with Annex A; and
b) fault protection is provided by protective equipotential bonding and automatic disconnection in case of a fault in accordance with **4.2.11.3** to **4.2.11.6**.

NOTE —Where this protective measure is applied, Class II equipment may also be used.

Where specified, additional protection is provided by a residual current protective device (RCD) with rated residual operating current not exceeding 30 mA, in accordance with **4.2.15.1**. System Voltage Independent RCD shall be used for domestic and similar application.

NOTE — Residual current monitors (RCMs) are not protective devices but they may be used to monitor residual currents in electrical installations. RCMs produce an audible or audible and visual signal when a preselected value of residual current is exceeded.

4.2.11.2 *Requirements for basic protection*

All electrical equipment shall comply with one of the

provisions for basic protection (protection against direct contact) described in Annex A or, where appropriate, Annex B.

4.2.11.3 *Requirements for fault protection*

4.2.11.3.1 *Protective earthing and protective equipotential bonding*

4.2.11.3.1.1 *Protective earthing*

Exposed conductive parts shall be connected to a protective conductor under the specific conditions for each type of system earthing as specified in **4.2.11.4** to **4.2.11.6**.

Simultaneously accessible exposed conductive parts shall be connected to the same earthing system individually, in groups or collectively.

Conductors for protective earthing shall comply with **5.4** and IS 3043.

Each circuit shall have available a protective conductor connected to the relevant earthing terminal.

4.2.11.3.1.2 *Protective equipotential bonding*

In each building the earthing conductor, the main earthing terminal and the following conductive parts shall be connected to the protective equipotential bonding:

a) metallic pipes supplying services into the building, for example, gas, water;
b) structural extraneous conductive parts, if accessible in normal use, metallic central heating and air-conditioning systems; and
c) metallic reinforcements of constructional reinforced concrete, if reasonably practicable.

Where such conductive parts originate outside the building, they shall be bonded as close as practicable to their point of entry within the building.

Conductors for protective equipotential bonding shall comply with **5.4** and IS 3043.

Any metallic sheath of telecommunication cables shall be connected to the protective equipotential bonding, taking account of the requirements of the owners or operators of these cables.

4.2.11.3.2 *Automatic disconnection in case of a fault*

4.2.11.3.2.1 Except as provided by **4.2.11.3.2.5** and **4.2.11.3.2.6**, a protective device shall automatically interrupt the supply to the line conductor of a circuit or equipment in the event of a fault of negligible impedance between the line conductor and an exposed-conductive-part or a protective conductor in the circuit or equipment within the disconnection time required in **4.2.11.3.2.2**, **4.2.11.3.2.3** or **4.2.11.3.2.4**.

NOTES

1 Higher values of disconnection time than those required in this sub-clause may be admitted in systems for electricity distribution to the public and power generation and transmission for such systems.

2 Lower values of disconnection time may be required for special installations or locations according to the IEC 60364-7.

3 For IT systems, automatic disconnection is not usually required on the occurrence of a first fault (*see* **4.2.11.6.1**). For the requirements for disconnection after the first fault *see* **4.2.11.6.4**.

4.2.11.3.2.2 The maximum disconnection time stated in Table 1 shall be applied to final circuits.

4.2.11.3.2.3 In TN systems, a disconnection time not exceeding 5s is permitted for distribution circuits, and for circuits not covered by **4.2.11.3.2.2**.

4.2.11.3.2.4 In TT systems, a disconnection time not exceeding 1s is permitted for distribution circuits and for circuits not covered by **4.2.11.3.2.2**.

4.2.11.3.2.5 If automatic disconnection according to **4.2.11.3.2.1** cannot be achieved in the time required

Table 1 Maximum Disconnection Times
(*Clause* 4.2.11.3.2.2)

System	50 V < U_o ≤ 120 V s		120 V < U_o ≤ 230 V s		230 V < U_o ≤ 400 V s		U_o > 400 V s	
	a.c.	d.c.	a.c.	d.c.	a.c.	d.c.	a.c.	d.c.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
TN	0.8	Note 1	0.4	5	0.2	0.4	0.1	0.1
TT	0.3	Note 1	0.2	0.4	0.07	0.2	0.04	0.1

Where in TT systems the disconnection is achieved by an overcurrent protective device and the protective equipotential bonding is connected with all extraneous-conductive-parts within the installation, the maximum disconnection times applicable to TN systems may be used.

U_o is the nominal a.c. or d.c. line to earth voltage.

NOTES

1 Disconnection may be required for reasons other than protection against electric shock.

2 Where disconnection is provided by an RCD *see* Note to **4.2.11.4.4**, Note 4 to **4.2.11.5.3** and Note to **4.2.11.6.4**.

by **4.2.11.3.2.2**, **4.2.11.3.2.3**, or **4.2.11.3.2.4** as appropriate, supplementary protective equipotential bonding shall be provided in accordance with **4.2.15.2**.

4.2.11.3.3 *Additional protection*

In a.c. systems, additional protection by means of a residual current protective device (RCD) in accordance with **4.2.15.1** shall be provided for:

a) at the incomer of every sub-distribution board having one or more outgoing circuits with fixed installation and socket-outlets to ensure safety of user from earth leakage, and
b) mobile equipment.

System voltages independent RCD not exceeding 30 mA shall be used for domestic and similar application of a particular item of equipment.

NOTE — An exemption may be made for:

a) Socket-outlets for use under the supervision of skilled or instructed persons, for example, in some commercial or industrial locations, or

b) A specific socket-outlet provided for connection.

4.2.11.4 *TN system*

4.2.11.4.1 In TN systems the integrity of the earthing of the installation depends on the reliable and effective connection of the PEN or PE conductors to earth. Where the earthing is provided from a public or other supply system, compliance with the necessary conditions external to the installation is the responsibility of the supply network operator.

NOTE — Examples of conditions include:

a) the PEN is connected to earth at a number of points and is installed in such a way as to minimize the risk of a break in the PEN conductor;

b) $R_B/R_E \leq 50/(U_o - 50)$

where

R_B= earth electrode resistance, in ohms, of all earth electrodes in parallel;

R_E= minimum contact resistance with earth, in ohms, of extraneous-conductive-parts not connected to a protective conductor, through which a fault between line and earth may occur; and

U_o= nominal a.c. r.m.s. voltage to earth, in volts.

4.2.11.4.2 The neutral point or the midpoint of the power supply system shall be earthed. If a neutral point or midpoint is not available or not accessible, a line conductor shall be earthed.

Exposed conductive parts of the installation shall be connected by a protective conductor to the main earthing terminal of the installation which shall be connected to the earthed point of the power supply system.

NOTES

1 If other effective earth connections exist, it is recommended that the protective conductors also be connected to such points wherever possible. Earthing at additional points, distributed as evenly as possible, may be necessary to ensure that the potentials of protective conductors remain, in case of a fault, as near as possible to that of earth. In large buildings such as high-rise buildings, additional earthing of protective conductors is not possible for practical reasons. In such buildings protective-equipotential-bonding between protective conductors and extraneous-conductive-parts has, however, a similar function.

2 It is recommended that protective conductors (PE and PEN) should be earthed where they enter any buildings or premises taking account of any diverted neutral currents.

4.2.11.4.3 In fixed installations, a single conductor may serve both as a protective conductor and as a neutral conductor (PEN conductor) provided that the requirements of **5.4.3.4** are satisfied. No switching or isolating device shall be inserted in the PEN conductor.

4.2.11.4.4 The characteristics of the protective devices (*see* **4.2.11.4.5**) and the circuit impedances shall fulfil the following requirement:

$$Z_s \times I_a \leq U_o$$

where

Z_s = the impedance in ohms (Ω) of the fault loop comprising

– the source,

– the line conductor up to the point of the fault, and

– the protective conductor between the point of the fault and the source;

I_a = the current in amperes (A) causing the automatic operation of the disconnecting device within the time specified in **4.2.11.3.2.2** or **4.2.11.3.2.3**. When a residual current protective device (RCD) is used this current is the residual operating current providing disconnection in the time specified in **4.2.11.3.2.2** or **4.2.11.3.2.3**.

U_o = the nominal a.c. or d.c. line to earth voltage in volts (V).

NOTE — Where compliance with this sub-clause is provided by an RCD, the disconnecting times in accordance with Table 1 relate to prospective residual fault currents significantly higher than the rated residual operating current of the RCD (typically $5 I_{\Delta n}$).

4.2.11.4.5 In TN systems, the following protective devices may be used for fault protection (protection against indirect contact):

– overcurrent protective devices;
– residual current protective devices (RCDs).

NOTE — Where an RCD is used for fault protection the circuit should also be protected by an overcurrent protective device in accordance with **4.4**.

A residual current protective device (RCD) shall not

be used in TN-C systems.

Where an RCD is used in a TN-C-S system, a PEN conductor shall not be used on the load side. The connection of the protective conductor to the PEN conductor shall be made on the source side of the RCD.

NOTE — Where discrimination between RCDs is necessary, *see* **5.3.6.3**.

4.2.11.5 *TT system*

4.2.11.5.1 All exposed conductive parts collectively protected by the same protective device shall be connected by the protective conductors to an earth electrode common to all those parts. Where several protective devices are utilized in series, this requirement applies separately to all the exposed-conductive-parts protected by each device.

The neutral point or the mid-point of the power supply system shall be earthed. If a neutral point or mid-point is not available or not accessible, a line conductor shall be earthed.

4.2.11.5.2 Generally in TT systems, RCDs shall be used for fault protection.

NOTES

1 Where an RCD is used for fault protection the circuit should also be protected by an overcurrent protective device in accordance with **4.4**.

2 The use of fault-voltage operated protective devices is not covered by this standard.

4.2.11.5.3 Where a residual current protective device (RCD) is used for fault protection, the following conditions shall be fulfilled:

a) the disconnection time as required by **4.2.11.3.2.2** or **4.2.11.3.2.4**, and

b) $R_A \times I_{\Delta n} \leq 50$ V

where

R_A = the sum of the resistance (in Ω) of the earth electrode and the protective conductor for the exposed conductive-parts, and

$I_{\Delta n}$ = the rated residual operating current of the RCD.

NOTES

1 Fault protection is provided in this case also if the fault impedance is not negligible.

2 Where discrimination between RCDs is necessary, *see* **5.3.6.3**.

3 Where R_A is not known, it may be replaced by Z_S.

4 The disconnection times in accordance with Table 1 relate to prospective residual fault currents significantly higher than the rated residual operating current of the RCD (typically 5 $I_{\Delta n}$).

4.2.11.6 *IT system*

4.2.11.6.1 In IT systems live parts shall be insulated from earth or connected to earth through a sufficiently high impedance. This connection may be made either at the neutral point or mid-point of the system or at an artificial neutral point. The latter may be connected directly to earth if the resulting impedance to earth is sufficiently high at the system frequency. Where no neutral point or mid-point exists, a line conductor may be connected to earth through a high impedance.

The fault current is then low in the event of a single fault to an exposed conductive part or to earth and automatic disconnection in accordance with **4.2.11.3.2** is not imperative provided the condition in **4.2.11.6.2** is fulfilled. Provisions shall be taken, however, to avoid risk of harmful patho-physiological effects on a person in contact with simultaneously accessible exposed conductive parts in the event of two faults existing simultaneously.

NOTE — To reduce overvoltage or to damp voltage oscillation, it may be necessary to provide earthing through impedances or artificial neutral points, and the characteristics of these should be appropriate to the requirements of the installation.

4.2.11.6.2 Exposed conductive parts shall be earthed individually, in groups, or collectively.

The following condition shall be fulfilled:

– in a.c. systems $R_A \times I_d \leq 120$ V

– in d.c. systems $R_A \times I_d \leq 120$ V

where

R_A = the sum of the resistance in W of the earth electrode and protective conductor for the exposed conductive parts; and

I_d = the fault current in A of the first fault of negligible impedance between a line conductor and an exposed conductive part. The value of I_d takes account of leakage currents and the total earthing impedance of the electrical installation.

4.2.11.6.3 In IT systems the following monitoring devices and protective devices may be used:

a) insulation monitoring devices (IMDs);

b) residual current monitoring devices (RCMs);

c) insulation fault location systems;

d) overcurrent protective devices; and

e) residual current protective devices (RCDs).

NOTE — Where a residual current operating device (RCD) is used, tripping of the RCD in event of a first fault cannot be excluded due to capacitive leakage currents.

4.2.11.6.3.1 In cases where an IT system is used for reasons of continuity of supply, an insulation monitoring device shall be provided to indicate the occurrence of a first fault from a live part to exposed conductive parts or to earth. This device shall initiate an audible and/or

visual signal which shall continue as long as the fault persists.

If there are both audible and visible signals, it is permissible for the audible signal to be cancelled.

NOTE — It is recommended that a first fault be eliminated with the shortest practicable delay.

4.2.11.6.3.2 Except where a protective device is installed to interrupt the supply in the event of the first earth fault, an RCM or an insulation fault location system may be provided to indicate the occurrence of a first fault from a live part to exposed conductive parts or to earth. This device shall initiate an audible and/or visual signal, which shall continue as long as the fault persists.

If there are both audible and visual signals it is permissible for the audible signal to be cancelled, but the visual alarm shall continue as long as the fault persists.

NOTE — It is recommended that a first fault be eliminated with the shortest practicable delay.

4.2.11.6.4 After the occurrence of a first fault, conditions for automatic disconnection of supply in the event of a second fault occurring on a different live conductor shall be as follows:

a) Where exposed conductive parts are interconnected by a protective conductor collectively earthed to the same earthing system, the conditions similar to a TN system apply and the following conditions shall be fulfilled where the neutral conductor is not distributed in a.c. systems and in d.c. systems where the mid-point conductor is not distributed:

$$2I_a Z_s \leq U$$

or where the neutral conductor or mid-point conductor respectively is distributed:

$$2I_a Z'_s \leq U_o$$

where

U_o = the nominal a.c. or d.c. voltage, in V, between line conductor and neutral conductor or mid-point conductor, as appropriate;

U = the nominal a.c. or d.c. voltage in V between line conductors;

Z_s = the impedance in Ω of the fault loop comprising the line conductor and the protective conductor of the circuit;

Z'_s = the impedance in Ω of the fault loop comprising the neutral conductor and the protective conductor of the circuit; and

I_a = the current in A causing operation of the protective device within the time required in **4.2.11.3.2.2** for TN systems or **4.2.11.3.2.3**.

NOTES

1 The time stated in Table 1 of **4.2.11.3.2.2** for the TN system is applicable to IT systems with a distributed or non-distributed neutral conductor or mid-point conductor.

2 The factor 2 in both formulas takes into account that in the event of the simultaneous occurrence of two faults, the faults may exist in different circuits.

3 For fault loop impedance, the most severe case should be taken into account, for example, a fault on the line conductor at the source and simultaneously another fault on the neutral conductor of a current-using equipment of the circuit considered.

b) Where the exposed-conductive-parts are earthed in groups or individually, the following condition applies:

$$R_A \times I_a \leq 50 \text{ V}$$

where

R_A = the sum of the resistances of the earth electrode and the protective conductor to the exposed conductive parts,

I_a = the current causing automatic disconnection of the disconnection device in a time complying to that for TT systems in Table 1 of **4.2.11.3.2.2** or in a time complying to **4.2.11.3.2.4**.

NOTE — If compliance to the requirements of (b) is provided by a residual current protective device (RCD) compliance with the disconnection times required for TT systems in Table 1 may require residual currents significantly higher than the rated residual operating current $I_{\Delta n}$ of the RCD applied (typically 5 $I_{\Delta n}$).

4.2.11.7 *Functional extra-low voltage* (*FELV*)

4.2.11.7.1 *General*

Where, for functional reasons, a nominal voltage not exceeding 50 V a.c. or 120 V d.c. is used but all the requirements of **4.2.14** relating to SELV or to PELV are not fulfilled, and where SELV or PELV is not necessary, the supplementary provisions described in **4.2.11.7.2** and **4.2.11.7.3** shall be taken to ensure basic protection and fault protection. This combination of provisions is known as FELV.

NOTE — Such conditions may, for example, be encountered when the circuit contains equipment (such as transformers, relays, remote-control switches, contactors) insufficiently insulated with respect to circuits at higher voltage.

4.2.11.7.2 *Requirements for basic protection*

Basic protection shall be provided by either,

a) basic insulation according to **A-1** corresponding to the nominal voltage of the primary circuit of the source, or

b) barriers or enclosures in accordance with **A-2**.

4.2.11.7.3 *Requirements for fault protection*

The exposed conductive parts of the equipment of the FELV circuit shall be connected to the protective conductor of the primary circuit of the source, provided that the primary circuit is subject to protection by automatic disconnection of supply described in **4.2.11.3** to **4.2.11.6**.

4.2.11.7.4 *Sources*

The source of the FELV system shall be either a transformer with at least simple separation between windings or shall comply with **4.2.14.3**.

NOTE — If the system is supplied from a higher voltage system by equipment which does not provide at least simple separation between that system and the FELV system, such as autotransformers, potentiometers, semiconductor devices, etc., the output circuit is deemed to be an extension of the input circuit and should be protected by the protective measure applied in the input circuit.

4.2.11.7.5 *Plugs and socket-outlets*

Plugs and socket-outlets for FELV systems shall comply with all the following requirements:

a) plugs shall not be able to enter socket-outlets of other voltage systems,
b) socket-outlets shall not admit plugs of other voltage systems, and
c) socket-outlets shall have a protective conductor contact.

4.2.12 *Protective Measure: Double or Reinforced Insulation*

4.2.12.1 *General*

4.2.12.1.1 Double or reinforced insulation is a protective measure in which,

a) basic protection is provided by basic insulation, and fault protection is provided by supplementary insulation, or
b) basic and fault protection is provided by reinforced insulation between live parts and accessible parts.

NOTE — This protective measure is intended to prevent the appearance of dangerous voltage on the accessible parts of electrical equipment through a fault in the basic insulation.

4.2.12.1.2 The protective measure by double or reinforced insulation is applicable in all situations, unless some limitations are as given in IEC 60364-7.

4.2.12.1.3 Where this protective measure is to be used as the sole protective measure (that is, where a whole installation or circuit is intended to consist entirely of equipment with double insulation or reinforced insulation), it shall be verified that the installation or circuit concerned will be under effective supervision in normal use so that no change is made that would impair the effectiveness of the protective measure. This protective measure shall not, therefore, be applied to any circuit that includes a socket-outlet or where a user may change items of equipment without authorization.

4.2.12.2 *Requirements for basic protection and fault protection*

4.2.12.2.1 *Electrical equipment*

Where the protective measure, using double or reinforced insulation, is used for the complete installation or part of the installation, electrical equipment shall comply with one of the following sub-clauses:

– **4.2.12.2.1.1**; or
– **4.2.12.2.1.2** and **4.2.12.2.2**; or
– **4.2.12.2.1.3** and **4.2.12.2.2**.

4.2.12.2.1.1 Electrical equipment shall be of the following types, and type tested and marked to the relevant standards:

a) electrical equipment having double or reinforced insulation (Class II equipment);
b) electrical equipment declared in the relevant product standard as equivalent to Class II, such as assemblies of electrical equipment having total insulation [*see* IS 8623 (Part 1)].

NOTE — This equipment is identified by the symbol ⧈ *see* IS 12032.

4.2.12.2.1.2 Electrical equipment having basic insulation only shall have supplementary insulation applied in the process of erecting the electrical installation, providing a degree of safety equivalent to electrical equipment according to **4.2.12.2.1.1** and complying with **4.2.12.2.2.1** to **4.2.12.2.2.3**.

NOTE — The symbol should be fixed in a visible position on the exterior and interior of the enclosure [*see* IEC 60417-5019 (DB: 2002-10) : Protective earth (ground)].

4.2.12.2.1.3 Electrical equipment having uninsulated live parts shall have reinforced insulation applied in the process of erecting the electrical installation, providing a degree of safety equivalent to electrical equipment according to **4.2.12.2.1.1** and complying with **4.2.12.2.2.2** and **4.2.12.2.2.3**; such insulation being recognized only where constructional features prevent the application of double insulation.

NOTE — The symbol should be fixed in a visible position on the exterior and interior of the enclosure [*see* IEC 60417-019 (DB: 2002-10): Protective earth (ground)].

4.2.12.2.2 *Enclosures*

4.2.12.2.2.1 The electrical equipment being ready for operation, all conductive parts separated from live parts by basic insulation only, shall be contained in an insulating enclosure affording at least the degree of protection IPXXB or IP2X.

4.2.12.2.2.2 The following requirements apply as specified:

a) the insulating enclosure shall not be traversed by conductive parts likely to transmit a potential; and
b) the insulating enclosure shall not contain any screws or other fixing means of insulating material which might need to be removed, or are likely to be removed, during installation and maintenance and whose replacement by metallic screws or other fixing means could impair the enclosure's insulation.

Where the insulating enclosure must be traversed by mechanical joints or connections (for example, for operating handles of built-in apparatus), these should be arranged in such a way that protection against shock in case of a fault is not impaired.

4.2.12.2.2.3 Where lids or doors in the insulating enclosure can be opened without the use of a tool or key, all conductive parts, which are accessible if the lid or door is open, shall be behind an insulating barrier (providing a degree of protection not less than IPXXB or IP2X) preventing persons from coming unintentionally into contact with those conductive parts. This insulating barrier shall be removable only by use of a tool or key.

4.2.12.2.2.4 Conductive parts enclosed in the insulating enclosure shall not be connected to a protective conductor. However, provision may be made for connecting protective conductors which necessarily run through the enclosure in order to serve other items of electrical equipment whose supply circuit also runs through the enclosure. Inside the enclosure, any such conductors and their terminals shall be insulated as though they were live parts, and their terminals shall be marked as PE terminals.

Exposed conductive parts and intermediate parts shall not be connected to a protective conductor unless specific provision for this is made in the specifications for the equipment concerned.

4.2.12.2.2.5 The enclosure shall not adversely affect the operation of the equipment protected in this way.

4.2.12.2.3 *Installation*

4.2.12.2.3.1 The installation of equipment mentioned in **4.2.12.2.1** (fixing, connection of conductors, etc) shall be effected in such a way as not to impair the protection afforded in compliance with the equipment specification.

4.2.12.2.3.2 Except where **4.2.12.1.3** applies, a circuit supplying items of Class II equipment shall have a circuit protective conductor run to and terminated at each point in wiring and at each accessory.

NOTE — This requirement is intended to take account of the replacement by the user of Class II equipment by Class I equipment.

4.2.12.2.4 *Wiring systems*

4.2.12.2.4.1 Wiring systems installed in accordance with **5.2** are considered to meet the requirements of **4.2.12.2** if:

a) the rated voltage of the wiring system shall be not less than the nominal voltage of the system and at least 300/500 V, and
b) adequate mechanical protection of the basic insulation is provided by one or more of the following:
   1) the non-metallic sheath of the cable, or
   2) non-metallic trunking or ducting complying with IS 14297 (Part 1) and IS 14927 (Part 2/Section 1), or non-metallic conduit complying with either is IS 9537 or the IS 14930 (Parts 1 and 2).

NOTES

1 Cable product standards do not specify impulse withstand capability. However, it is considered that the insulation of the cabling system is at least equivalent to the requirement in IEC 61140 for reinforced insulation.

2 Such a wiring system should not be identified by the symbol  IEC 60417-5172 (DB: 2002-10), not by the symbol  IEC 60417-5019 (DB: 2002-10).

4.2.13 *Protective Measure: Electrical Separation*

4.2.13.1 *General*

4.2.13.1.1 Electrical separation is a protective measure in which,

a) basic protection is provided by basic insulation of live parts or by barriers and enclosures in accordance with Annex A, and
b) fault protection is provided by simple separation of the separated circuit from other circuits and from earth.

4.2.13.1.2 Except as permitted by **4.2.13.1.3**, this protective measure shall be limited to the supply of one item of current-using equipment supplied from one unearthed source with simple separation.

NOTE — When this protective measure is used, it is particularly important to ensure compliance of the basic insulation with the product standard.

4.2.13.1.3 Where more than one item of current-using equipment is supplied from an unearthed source with simple separation, the requirements of **C-3** shall be met.

4.2.13.2 *Requirements for basic protection*

All electrical equipment shall be subject to one of the basic protective provisions given in Annex A or to the protective measure in **4.2.12**.

4.2.13.3 *Requirements for fault protection*

4.2.13.3.1 Protection by electrical separation shall be ensured by compliance with **4.2.13.3.2** to **4.2.13.3.6**.

4.2.13.3.2 The separated circuit shall be supplied through a source with at least simple separation, and the voltage of the separated circuit shall not exceed 500 V.

4.2.13.3.3 Live parts of the separated circuit shall not be connected at any point to another circuit or to earth or to a protective conductor.

To ensure electrical separation, arrangements shall be such that basic insulation is achieved between circuits.

4.2.13.3.4 Flexible cables and cords shall be visible throughout any part of their length liable to mechanical damage.

4.2.13.3.5 For separated circuits the use of separate wiring systems is recommended. If separated circuits and other circuits are in the same wiring system, multi-conductor cables without metallic covering, insulated conductors in insulating conduit, insulated ducting or insulated trunking shall be used, provided that

a) the rated voltage is not less than the highest nominal voltage, and
b) each circuit is protected against overcurrent.

4.2.13.3.6 The exposed conductive parts of the separated circuit shall not be connected either to the protective conductor or exposed conductive parts of other circuits, or to earth.

NOTE — If the exposed-conductive-parts of the separated circuit are liable to come into contact, either intentionally or fortuitously, with the exposed-conductive-parts of other circuits, protection against electric shock no longer depends solely on protection by electrical separation but on the protective provisions to which the latter exposed-conductive-parts are subject.

4.2.14 *Protective Measure: Extra-Low-Voltage Provided by SELV and PELV*

4.2.14.1 *General*

4.2.14.1.1 Protection by extra-low-voltage is a protective measure which consists of either of two different extra-low-voltage systems:

– SELV; or
– PELV.

This protective measure requires:

a) limitation of voltage in the SELV or PELV system to the upper limit of Voltage Band I, 50 V a.c. or 120 V d.c. [*see* IS 12360 (Part 2)],
b) protective separation of the SELV or PELV system from all circuits other than SELV and PELV circuits, and basic insulation between the SELV or PELV system and other SELV or PELV systems; and
c) for SELV systems only, basic insulation between the SELV system and earth.

4.2.14.1.2 The use of SELV or PELV according to **4.2.14** is considered as a protective measure in all situations.

NOTE — In certain cases the standards of the IEC 60364-7 series limit the value of the extra-low voltage to a value lower than 50 V a.c. or 120 V d.c.

4.2.14.2 *Requirements for basic protection and fault protection*

Basic protection and fault protection is deemed to be provided when:

a) the nominal voltage cannot exceed the upper limit of Voltage Band I,
b) the supply is from one of the sources listed in **4.2.14.3**, and
c) the conditions of **4.2.14.4** are fulfilled.

NOTE — If the system is supplied from a higher voltage system by equipment which provides at least simple separation between that system and the extra-low-voltage system, but which does not meet the requirements for SELV and PELV sources in **4.2.14.3**, the requirements for FELV may be applicable (*see* **4.2.11.7**).

4.2.14.3 *Sources for SELV and PELV*

The following sources may be used for SELV and PELV systems.

4.2.14.3.1 A safety isolating transformer in accordance with IEC 61558-2-6.

4.2.14.3.2 A source of current providing a degree of safety equivalent to that of the safety isolating transformer specified in **4.2.14.3.1** (for example, motor generator with windings providing equivalent isolation).

4.2.14.3.3 An electrochemical source (for example, a battery) or another source independent of a higher voltage circuit (for example, a diesel-driven generator).

4.2.14.3.4 Certain electronic devices complying with appropriate standards where provisions have been taken in order to ensure that, even in the case of an internal fault, the voltage at the outgoing terminals cannot

exceed the values specified in **4.2.14.1.1**. Higher voltages at the outgoing terminals are, however, permitted if it is ensured that, in case of contact with a live part or in the event of a fault between a live part and an exposed-conductive-part, the voltage at the output terminals is immediately reduced to those values or less.

NOTES

1 Examples of such devices include insulation testing equipment and monitoring devices.

2 Where higher voltages exist at the outgoing terminals, compliance with this clause may be assumed if the voltage at the outgoing terminals is within the limits specified in **4.2.14.1.1** when measured with a voltmeter having an internal resistance of at least 3 000 Ω.

4.2.14.3.5 Mobile sources supplied at low voltage, for example, safety isolating transformers or motor generators, shall be selected or erected in accordance with the requirements for protection by the use of double or reinforced insulation (*see* **4.2.12**).

4.2.14.4 *Requirements for SELV and PELV circuits*

4.2.14.4.1 SELV and PELV circuits shall have:

a) basic insulation between live parts and other SELV or PELV circuits, and
b) protective separation from live parts of circuits not being SELV or PELV, provided by double or reinforced insulation or by basic insulation and protective screening for the highest voltage present.

SELV circuits shall have basic insulation between live parts and earth.

The PELV circuits and/or exposed conductive parts of equipment supplied by the PELV circuits may be earthed.

NOTES

1 In particular, protective separation is necessary between the live parts of electrical equipment such as relays, contactors, auxiliary switches, and any part of a higher voltage circuit or a FELV circuit.

2 The earthing of PELV circuits may be achieved by a connection to earth or to an earthed protective conductor within the source itself.

4.2.14.4.2 Protective separation of wiring systems of SELV and PELV circuits from the live parts of other circuits, which have at least basic insulation, may be achieved by one of the following arrangements:

a) SELV and PELV circuit conductors shall be enclosed in a non-metallic sheath or insulating enclosure in addition to basic insulation;
b) SELV and PELV circuit conductors shall be separated from conductors of circuits at voltages higher than Band I by an earthed metallic sheath or earthed metallic screen;
c) circuit conductors at voltages higher than Band I may be contained in a multi-conductor cable or other grouping of conductors if the SELV and PELV conductors are insulated for the highest voltage present;
d) the wiring systems of other circuits are in compliance with **4.2.12.2.4.1**; and
e) physical separation.

4.2.14.4.3 Plugs and socket-outlets in SELV and PELV systems shall comply with the following requirements:

a) plugs shall not be able to enter socket-outlets of other voltage systems;
b) socket-outlets shall not admit plugs of other voltage systems; and
c) plugs and socket-outlets in SELV systems shall not have a protective conductor contact.

4.2.14.4.4 Exposed conductive parts of SELV circuits shall not be connected to earth, or to protective conductors or exposed conductive parts of another circuit.

NOTE — If the exposed-conductive-parts of SELV circuits are liable to come into contact, either fortuitously or intentionally, with the exposed conductive parts of other circuits, protection against electric shock no longer depends solely on protection by SELV, but also on the protective provisions to which the latter exposed-conductive-parts are subject.

4.2.14.4.5 If the nominal voltage exceeds 25 V a.c. or 60 V d.c. or if the equipment is immersed, basic protection shall be provided for SELV and PELV circuits by:

a) insulation in accordance with **A-1**, or
b) barriers or enclosures in accordance with **A-2**.

Basic protection is generally unnecessary in normal dry conditions for:

a) SELV circuits where the nominal voltage does not exceed 25 V a.c. or 60 V d.c.;
b) PELV circuits where the nominal voltage does not exceed 25 V a.c. or 60 V d.c. and exposed conductive parts and/or the live parts are connected by a protective conductor to the main earthing terminal.

In all other cases, basic protection is not required if the nominal voltage of the SELV or PELV system does not exceed 12 V a.c. or 30 V d.c.

4.2.15 *Additional Protection*

NOTE — Additional protection may be specified with the protective measure under certain conditions of external influence and in certain special locations (*see* IEC 60364-7).

4.2.15.1 *Additional protection: residual current protective devices* (*RCDs*)

4.2.15.1.1 The use of RCDs with a rated residual

operating current not exceeding 30 mA, is recognized in a.c. systems as additional protection in the event of failure of the provision for basic protection and/or the provision for fault protection or carelessness by users. System voltage Independent RCD not exceeding 30 mA shall be used for domestic and similar application.

4.2.15.1.2 The use of such devices is not recognized as a sole means of protection and does not obviate the need to apply one of the protective measures specified in **4.2.11** to **4.2.14**.

4.2.15.2 *Additional protection: supplementary protective equipotential bonding*

NOTES

1 Supplementary protective equipotential bonding is considered as an addition to fault protection.

2 The use of supplementary protective bonding does not exclude the need to disconnect the supply for other reasons, for example, protection against fire, thermal stresses in equipment, etc.

3 Supplementary protective bonding may involve the entire installation, a part of the installation, an item of apparatus, or a location.

4.2.15.2.1 Supplementary protective equipotential bonding shall include all simultaneously accessible exposed conductive parts of fixed equipment and extraneous conductive parts including where practicable the main metallic reinforcement of constructional reinforced concrete. The equipotential bonding system shall be connected to the protective conductors of all equipment including those of socket-outlets.

4.2.15.2.2 Where doubt exists regarding the effectiveness of supplementary protective equipotential bonding, it shall be confirmed that the resistance R between simultaneously accessible exposed conductive parts and extraneous conductive parts fulfils the following condition:

$$R \leq \frac{120\text{V}}{I_a} \text{ in d.c. systems}$$

$$R \leq \frac{50\text{V}}{I_a} \text{ in a.c. system}$$

$$R \leq \frac{120\text{V}}{I_a} \text{ in d.c. systems}$$

where

I_a = the operating current in A of the protective device

– for residual current protective devices (RCDs), $I_{\Delta n}$

– for overcurrent devices, the 5s operating current.

4.3 Protection for Safety — Protection Against Thermal Effects

4.3.1 *Protection Against Fire Caused by Electrical Equipment*

4.3.1.1 *General requirements*

Persons, livestock and property shall be protected against damage or injury caused by heat or fire which may be generated or propagated in electrical installations by taking into account the requirements of this standard and the instructions of equipment manufacturers.

The heat generated by electrical equipment shall not cause danger or harmful effects to adjacent fixed material or to material which may foreseeable be in proximity to such equipment. Electrical equipment shall not present a fire hazard to adjacent materials.

NOTE — Damage, injury or ignition may be caused by effects such as

i) heat accumulation, heat radiation, hot elements,
ii) reduction of the safe function of electrical equipment, e.g. protective devices such as protective switchgear, thermostats, temperature limiters, seals of cable penetrations and wiring systems,
iii) overcurrent,
iv) insulation faults and/or arcs causing interference,
v) harmonic currents,
vi) lightning strikes (*see* IS/IEC 62305 series),
vii) overvoltages (*see* **4.5.3**),
viii) inappropriate selection or erection of equipment.

Any relevant manufacturer's erection instructions shall be taken into account in addition to the requirements of this standard.

4.3.1.2 *Where fixed equipment may attain surface temperatures which could cause a fire hazard to adjacent materials, the equipment shall either*

a) be mounted on or within materials that will withstand such temperatures and are of low thermal conductance, or
b) be screened from elements of building construction by materials which will withstand such temperatures and are of low thermal conductance, or
c) be mounted so as to allow safe dissipation of heat at a sufficient distance from any material on which such temperatures could have deleterious thermal effects, any means of support being of low thermal conductance.

4.3.1.3 Where arcs or sparks may be emitted by permanently connected equipment in normal service, the equipment shall either:

a) be totally enclosed in arc-resistant material, or
b) be screened by arc-resistant material from materials on which the emission could have harmful effects, or
c) be mounted so as to allow safe extinction of

the emissions at a sufficient distance from material upon which the emissions could have harmful effects.

Arc-resistant material used for this protective measure shall be non-ignitable, of low thermal conductivity, and of adequate thickness to provide mechanical stability.

NOTE — For example, a sheet made of fibreglass silicone of 20 mm thickness may be considered as arc-resistant.

4.3.1.4 Fixed equipment causing a concentration of heat shall be at a sufficient distance from any fixed object or building element so that the object or element, in normal conditions, is not subjected to a dangerous temperature.

For example, a temperature in excess of its ignition temperature.

NOTE — Any information from the manufacturer of the equipment should be taken into account.

4.3.1.5 Where electrical equipment in a single location contains flammable liquid in significant quantity, adequate precautions shall be taken to prevent the spread of liquid, flame and the products of combustion.

NOTES

1 Examples of such precautions include:

a) a retention pit to collect any leakage of liquid and ensure extinction in the event of fire;

b) installation of the equipment in a chamber of adequate fire resistance and the provision of sills or other means of preventing liquid spreading to other parts of the building, such a chamber being ventilated solely to the external atmosphere.

2 The generally accepted lower limit for a significant quantity is 25 l.

3 For quantities less than 25 l, it is sufficient to take precautions to prevent the escape of liquid.

4 Products of combustion of liquid are considered to be flame, smoke and gas.

5 It is desirable to switch off the supply at the onset of a fire.

4.3.1.6 The materials of enclosures installed around electrical equipment during erection shall withstand the highest temperature likely to be produced by the electrical equipment.

Combustible materials are not suitable for the construction of these enclosures unless preventive measures against ignition are taken, such as covering with non-combustible or not readily combustible material of low thermal conductivity.

4.3.2 *Precautions where Particular Risks of Fire Exist*

4.3.2.1 *General*

4.3.2.1.1 Electrical equipment shall be restricted to that necessary for the use of these locations, except wiring systems according to **4.3.2.3.5**.

4.3.2.1.2 Electrical equipment shall be so selected and erected that its temperature in normal use and foreseeable temperature rise during a fault cannot cause a fire.

These arrangements may be effected by the construction of equipment or its conditions of installation.

Special measures are not necessary where the temperature of surfaces is unlikely to cause ignition of nearby substances.

4.3.2.1.3 Thermal cut-out devices shall have manual resetting only.

4.3.2.2 *Conditions of evacuation in an emergency*

Condition BD2: Low density occupation, difficult conditions of evacuation

BD3: High density occupation, easy conditions of evacuation

BD4: High density occupation, difficult conditions of evacuation (according to Table 7 of **5.1**)

NOTE — Authorities responsible for building construction, public gatherings, fire prevention, etc may specify which BD condition is applicable.

4.3.2.2.1 In conditions BD2, BD3 and BD4, wiring systems shall not encroach on escape routes unless the wiring in the wiring system is provided with sheaths or enclosures, provided by the cable management system itself or by other means.

Wiring systems encroaching on escape routes shall not be within arm's reach unless they are provided with protection against mechanical damage likely to occur during an evacuation.

Wiring systems in escape routes shall be as short as practicable and shall be non-flame propagating.

NOTE — Compliance with this requirement may be achieved by using the following products:

a) Cables fulfilling tests under fire conditions of IEC 60332-1-2, and appropriate fire conditions as follows: IEC 60332-3-21, IEC 60332-3-22, IEC 60332-3-23, IEC 60332-3-24 and IEC 60332-3-25;
b) Conduit systems classified as non-flame propagating according to IS 14930 (Parts 1 & 2);
c) Cable trunking systems classified as non-flame propagating according to IS 14297 (Part 1) and IS 14927 (Part 2/ Section 1);
d) Cable tray systems and cable ladder systems classified as non-flame propagating according to IEC 61537; and
e) For powertrack systems: the IEC 61534 series.

In conditions BD2, BD3 and BD4, wiring systems that are supplying safety circuits shall have a resistance to fire rating of either the time authorized by regulations for building elements or 1h in the absence of such a regulation.

NOTE — For the requirements for maintaining the function of wiring systems of safety services under fire conditions, *see* **5.6**.

Wiring within escape routes shall have a limited rate of smoke production.

4.3.2.2.2 In conditions BD2, BD3 and BD4, switchgear and controlgear devices, except certain devices to facilitate evacuation, shall be accessible only to authorized persons. If they are placed in passages, they shall be enclosed in cabinets or boxes constructed of non-combustible or not readily combustible material.

NOTE —This clause does not prohibit plastic enclosures that are not readily combustible.

4.3.2.2.3 In conditions BD3 and BD4 and in escape routes, electrical equipment containing flammable liquids shall not be installed.

NOTE — Individual capacitors incorporated in equipment are not subject to this requirement. This exception principally concerns discharge luminaires and capacitors of motor starters.

4.3.2.3 *Locations with risks of fire due to the nature of processed or stored materials*

Condition BE2: Fire risk (according to Table 7 of **5.1**)

NOTES

1 Quantities of flammable materials or the surface or volume of the location may be regulated by national authorities.

2 For explosion risks, *see* IS/ IEC 60079-14.

4.3.2.3.1 Luminaires shall be kept at an adequate distance from combustible materials. If no other information is given by manufacturers, spotlights and projectors shall be installed at the following minimum distances from combustible materials:

100 W	0.5 m
100 W to 300 W	0.8 m
300 W to 500 W	1.0 m
above 500 W	greater distances can be necessary.

NOTE — In the absence of manufacturers' instructions, the above distances imply all directions.

Lamps and other components of luminaires shall be protected against foreseeable mechanical stresses. Such protective means shall not be fixed on lampholders unless they form an integral part of the luminaire. Modifications to luminaires are not acceptable.

A luminaire with a lamp that could eject flammable materials in case of failure shall be installed with a safety protective shield for the lamp in accordance with the manufacturer's instructions.

NOTE — Luminaires suitable for direct mounting on normally flammable surfaces were earlier marked with the symbol F according to IS 10322.

With the publication of IEC 60598-1 : 2008, luminaires suitable for direct mounting have no special marking and only luminaires not suitable for mounting on normally flammable surfaces are marked with symbols:

and/or

(*see* **N.4** of IEC 60598-1 : 2008 for further explanations).

4.3.2.3.2 Measures shall be taken to prevent an electrical enclosure of equipment such as a heater or resistor from exceeding the following temperatures:

a) 90 °C under normal conditions, and
b) 115 °C under fault conditions.

Where materials such as dust or fibres sufficient to cause a fire hazard could accumulate on an enclosure of electrical equipment, adequate measures shall be taken to prevent that enclosure from exceeding the temperatures stated above.

NOTE — Luminaires marked in compliance with IS 10322 are designed to provide limited surface temperature.

4.3.2.3.3 Switchgear for protection, control and isolation shall be placed outside locations presenting condition BE2, unless it is in an enclosure providing a degree of protection appropriate for such a location of at least IP4X or, in the presence of dust, IP5X or, in the presence of conductive dust, IP6X, except where **4.3.2.3.11** applies.

4.3.2.3.4 Except where wiring and wiring systems are embedded in non-combustible material, only non-flame-propagating wiring systems shall be used.

As a minimum, equipment shall be selected in accordance with the following requirements:

a) Cables shall satisfy the test under fire conditions specified in the IEC 60332 series;
b) Conduit systems shall satisfy the test for resistance to flame propagation specified in IS 14930 (Parts 1 and 2);
c) Cable trunking systems and cable ducting systems shall satisfy the test for resistance to flame propagation specified in IS 14297 (Part 1) and IS 14297 (Part 2/Section 1);
d) Cable tray systems and cable ladder systems shall satisfy the test for resistance to flame propagation specified in IEC 61537 series; and
e) Powertrack systems shall satisfy the test for resistance to flame propagation specified in IEC 61534 series.

NOTES

1 Where the risk of flame propagation is high, e.g. in long vertical runs of bunched cables, cables should meet the flame propagation characteristics of the appropriate part in the IEC 60332-3 series.

2 Flame propagation tests for cable management systems are always performed in a vertical configuration.

4.3.2.3.5 Wiring systems which traverse these locations, but are not necessary for the use of the locations, shall satisfy the following conditions:

a) the wiring systems shall meet the requirements of **4.3.2.3.5**;
b) they have no connection along the route inside the locations, unless these connections are placed in fire-resistant enclosures;
c) they are protected against overcurrent in accordance with **4.3.2.3.10**; and
d) bare conductors shall not be used.

4.3.2.3.6 In forced-air heating installations, the air intake shall be outside locations where a presence of combustible dust may be expected.

The temperature of the outgoing air shall not be such as to cause fire in the location.

4.3.2.3.7 Motors which are automatically or remotely controlled, or which are not continuously supervised, shall be protected against excessive temperature rise by temperature responsive devices, unless specifically designed to be inherently heat-limiting.

4.3.2.3.8 Every luminaire shall:

a) be appropriate for the location;
b) be provided with an enclosure providing a degree of protection of at least IP4X or, in the presence of dust, IP5X or, in the presence of conductive dust, IP6X;
c) have a limited surface temperature in accordance with IEC 60598-2-24; and
d) be of a type that prevents lamp components from falling from the luminaire.

In locations where there may be fire hazards due to dust or fibres, luminaires shall be installed so that dust or fibres cannot accumulate in dangerous amounts.

NOTE — Luminaires should also comply with relevant parts of the IEC 60598 series (*see also* **5.5.3**).

4.3.2.3.9 Final circuits and current-using equipment shall be protected against insulation faults as follows:

a) In TN and TT systems, RCDs with a rated residual operating current $I_{\Delta n}$ 300 mA shall be used. Where resistive faults may cause a fire, for example, for overhead heating with heating film elements, the rated residual operating current shall be $I_{\Delta n}$ 30 mA.
b) In IT systems, insulation monitoring devices monitoring the whole installation or RCMs (residual current monitoring devices) in the final circuits, both with audible and visual signals, shall be provided. Alternatively, RCDs with a rated residual operating current as specified in (a) may be used. In the event of a second fault, *see* **4.2.11** for disconnection times.

Mineral insulated cables and busbar trunking systems are not considered likely to cause a fire from insulation faults and therefore need not be protected.

NOTE — Cables with metallic coverings are recommended. The metallic covering should be connected to the protective conductor.

4.3.2.3.10 Circuits supplying or traversing locations where condition BE2 applies, shall be protected against overload and short-circuit by protective devices located outside and on the supply side of these locations. Circuits originating inside the locations shall be protected against overcurrent by protective devices located at their origin.

4.3.2.3.11 In circuits supplied at SELV or PELV, live parts shall be:

a) contained in enclosures affording the degree of protection IP2X or IPXXB, or
b) provided with insulation capable of withstanding a test voltage of 500 V d.c. for 1 min regardless of the nominal voltage of the circuit. This is in addition to the requirements of **4.2.14.4.5**.

4.3.2.3.12 PEN conductors are not allowed in locations where condition BE2 applies, except for circuits traversing such locations and having no connection between their traversing PEN conductor and any conductive part in the locations.

4.3.2.3.13 Every circuit supplying equipment in locations where condition BE2 applies shall be provided with a means of isolation from all live supply conductors such that no live supply conductor can remain closed when one or more others are open. This may be achieved, for example, by a mechanically linked switch or a mechanically linked circuit-breaker.

NOTE — Provision may be made for isolation of a group of circuits by a common means, if the service conditions allow this.

4.3.2.4 *Locations with combustible constructional materials*

Condition CA2: Combustible materials (according to Table 7 of **5.1**).

4.3.2.4.1 Precautions shall be taken to ensure that electrical equipment cannot cause the ignition of walls, floors or ceilings. This can be achieved by proper design, choice and installation of electrical equipment.

To avoid the ingress of solid foreign objects, boxes and enclosures installed in prefabricated hollow walls liable to be drilled during erection of the wall shall have a degree of protection of at least IP3X.

4.3.2.4.2 Luminaires shall be kept at an adequate distance from combustible materials. If no other information is given by manufacturers, spotlights and projectors shall be installed at the following minimum distances from combustible materials:

100 W	0.5 m
100 W to 300 W	0.8 m
300 W to 500 W	1.0 m
above 500 W	greater distances can be necessary.

NOTE — In the absence of manufacturers' instructions, the above distances imply all directions.

Lamps and other components of luminaires shall be protected against foreseeable mechanical stresses. Such protective means shall not be fixed on lampholders, unless they form an integral part of the luminaire.

A luminaire with a lamp that could eject flammable materials in case of failure shall be installed with a safety protective shield for the lamp in accordance with the manufacturer's instructions.

NOTE — Luminaires suitable for direct mounting on normally flammable surfaces were earlier marked with the symbol 

according to IS 10322.

With the publication of IEC 60598-1 : 2008, luminaires suitable for direct mounting have no special marking and only luminaires not suitable for mounting on normally flammable surfaces are marked with symbols

 and/or 

(*see* **N.4** of IEC 60598-1 : 2008 for further explanations).

4.3.2.5 *Fire propagating structures*

Condition CB2: Propagation of fire (according to Table 7 of **5.1**).

4.3.2.5.1 In structures where the shape and dimensions facilitate the spread of fire, precautions shall be taken to ensure that the electrical installation cannot propagate a fire (for example, chimney effect).

NOTE — Fire detectors may be provided which ensure the implementation of measures for preventing propagation of fire, for example, the closing of fire-proof shutters in ducts, building voids and the like. Boxes and enclosures according to IS 14772 for hollow walls and cables in accordance with the IEC 60332-3 series can be used. IS 14772 includes marking with the symbol H for boxes and enclosures for hollow walls.

4.3.2.6 *Selection and erection of installations in locations with endangering of irreplaceable goods*

The requirements of **4.3.2.1.2** shall be met.

NOTES

1 The locations include buildings or rooms with assets of significant value. Examples include: national monuments, museums and other public buildings. Buildings such as railway stations and airports, buildings or facilities such as laboratories, computer centres and certain industrial and storage facilities.

2 The following measures may be considered:

a) installation of mineral insulated cables according to IEC 60702-1;
b) installation of cables with improved fire-resisting characteristics in case of a fire hazard, and complying with IEC 60331-1 or IEC 60331-21 or similar;
c) installation of cables in non-combustible solid walls, ceilings and floors;
d) installation of cables in areas with constructional partitions having a fire-resisting capability for a time of 30 min or 90 min, the latter in locations housing staircases and needed for an emergency escape.

Where these measures are not practicable, enhanced fire protection may be possible by use of reactive fire protection systems.

4.3.3 *Protection against Burns*

Accessible parts of electrical equipment within arm's reach shall not attain a temperature likely to cause burns to persons, and shall comply with the appropriate limit stated in Table 2. All parts of the installation likely in normal service to attain, even for short periods, temperatures exceeding the limits stated in Table 2 shall be guarded so as to prevent any accidental contact. However, the values in Table 2 do not apply to equipment complying with IS standards for the type of equipment concerned.

NOTE — Lower temperatures may be applicable where condition BA2 (children) applies.

Table 2 Temperature Limits in Normal Service for Accessible Parts of Equipment within Arm's Reach

(*Clause* 4.3.3)

Accessible Parts	Material of Accessible Surfaces	Maximum Temperatures °C
(1)	(2)	(3)
Hand-held means of operation	Metallic	55
	Non-metallic	65
Parts intended to be touched but not hand-held	Metallic	70
	Non-metallic	80
Parts which need not be touched for normal operation	Metallic	80
	Non-metallic	90

4.3.4 *Protection Against Overheating*

4.3.4.1 *Forced air heating systems*

Forced air heating systems shall be such that their heating elements, other than those of central storage heaters, cannot be activated until the prescribed air flow has been established and are deactivated when the air flow is less than the prescribed value. In addition, they shall have two temperature limiting devices

independent of each other which prevent permissible temperatures from being exceeded in air ducts.

Supporting parts, frames and enclosures of heating elements shall be of non-combustible material.

4.3.4.2 *Appliances producing hot water or steam*

All appliances producing hot water or steam shall be protected by design or erection against overheating in all service conditions. Unless the appliances comply as a whole with the appropriate Indian standards, the protection shall be by means of an appropriate non-self-resetting device, functioning independently of the thermostat.

If an appliance has no free outlet, it shall also be provided with a device which limits the internal water pressure.

4.3.4.3 *Space heating appliances*

The frame and enclosure of space heating appliances shall be of non-combustible material.

NOTE — In operating areas with a fire risk, space heating appliances may not be operated if the air from these areas is guided through the appliance.

The side walls of radiant heaters which are not touched by the heat radiation should have a sufficient distance from flammable parts. In case of a reduction of the distance by a non-flammable partition, this partition should have a distance of at least 1 cm to the enclosure of the radiant heater and to flammable parts.

Unless otherwise declared by the manufacturer, radiant heaters should be mounted so that in the direction of radiation a safety distance of at least 2 m from flammable parts is ensured.

4.4 Protection for Safety — Protection Against Overcurrent

4.4.1 *General Requirements*

Protective devices shall be provided to disconnect any overcurrent in the circuit conductors before such a current could cause danger due to thermal or mechanical effects detrimental to insulation, joints, terminations or material surrounding the conductors.

4.4.2 *Requirements according to the Nature of the Circuits*

4.4.2.1 *Protection of line conductors*

4.4.2.1.1 Detection of overcurrent shall be provided for all line conductors, except where **4.4.2.1.2** applies. It shall cause the disconnection of the conductor in which the overcurrent is detected but not necessarily the disconnection of the other live conductors.

If disconnection of a single phase may cause danger, for example in the case of a three-phase motor, appropriate precautions shall be taken.

4.4.2.1.2 In a TT or TN system, for a circuit supplied between line conductors and in which the neutral conductor is not distributed, overcurrent detection need not be provided for one of the line conductors, provided that the following conditions are simultaneously fulfilled:

a) there exists, in the same circuit or on the supply side, protection intended to detect unbalanced loads and intended to cause disconnection of all the line conductors; and
b) the neutral conductor is not distributed from an artificial neutral point of the circuits situated on the load side of the protective device mentioned in (a).

4.4.2.2 *Protection of the neutral conductor*

4.4.2.2.1 *TT or TN systems*

Where the cross-sectional area of the neutral conductor is at least equivalent to that of the line conductors, and the current in the neutral is expected not to exceed the value in the line conductors, it is not necessary to provide overcurrent detection for the neutral conductor or a disconnecting device for that conductor.

Where the cross-sectional area of the neutral conductor is less than that of the line conductors, it is necessary to provide overcurrent detection for the neutral conductor, appropriate to the cross-sectional area of that conductor; this detection shall cause the disconnection of the line conductors, but not necessarily of the neutral conductor.

In both cases the neutral conductor shall be protected against short-circuit current.

NOTE — This protection may be achieved by the overcurrent protective devices in the line conductors. In that case it is not necessary to provide overcurrent protection for the neutral conductor or a disconnecting device for that conductor.

Where the current in the neutral conductor is expected to exceed the value in the line conductors, refer to **4.4.2.2.3**.

Except for disconnection, the requirements for a neutral conductor apply to a PEN conductor.

4.4.2.2.2 *IT systems*

Where the neutral conductor is distributed, it is necessary to provide overcurrent detection for the neutral conductor of every circuit. The overcurrent detection shall cause the disconnection of all the live conductors of the corresponding circuit, including the neutral conductor. This measure is not necessary if;

a) the particular neutral conductor is effectively protected against overcurrent by a protective device placed on the supply side, for example at the origin of the installation, or
b) the particular circuit is protected by a residual current operated protective device with a rated residual current not exceeding 0.20 times the current-carrying capacity of the corresponding neutral conductor. This device shall disconnect all the live conductors of the corresponding circuit, including the neutral conductor. The device shall have sufficient breaking capacity for all poles.

NOTE — In IT systems, it is strongly recommended that the neutral conductor should not be distributed.

4.4.2.2.3 *Harmonic currents*

Overload detection shall be provided for the neutral conductor in a multi-phase circuit where the harmonic content of the line currents is such that the current in the neutral conductor is expected to exceed the current-carrying capacity of that conductor. The overload detection shall be compatible with the nature of the current through the neutral and shall cause the disconnection of the line conductors but not necessarily the neutral conductor. Where the neutral is disconnected, the requirements of **4.4.2.3** apply.

NOTE — Further requirements regarding protection of neutral conductors are given in **5.2**.

4.4.2.3 *Disconnection and reconnection of the neutral conductor in multi-phase systems*

Where disconnection of the neutral conductor is required, disconnection and reconnection shall be such that the neutral conductor shall not be disconnected before the line conductors and shall be reconnected at the same time as or before the line conductors.

4.4.3 *Nature of Protective Devices*

The protective devices shall be of the appropriate types indicated by **4.4.2.1** to **4.4.2.3**.

4.4.3.1 *Devices providing protection against both overload current and short-circuit current*

Except as stated in **4.4.5.5.1**, a device providing protection against both overload and short-circuit current shall be capable of breaking and, for a circuit-breaker, making any overcurrent up to and including the prospective short-circuit current at the point where the device is installed. Such devices may be:

a) circuit-breakers incorporating overload and short-circuit release;
b) circuit-breakers in conjunction with fuses; and
c) fuses having fuse links with gG characteristics.

NOTES

1 The fuse comprises all the parts that form the complete protective device.

2 This subclause does not exclude the use of other protective devices if the requirements in **4.4.3.1** and **4.4.5.5** are fulfilled.

4.4.3.2 *Devices ensuring protection against overload current only*

These protective devices shall satisfy the requirements of **4.4** and may have an interrupting capacity below the value of the prospective short-circuit current at the point where the devices are installed.

NOTES

1 These devices are generally inverse time lag protective devices.

2 Fuses type aM do not protect against overload.

4.4.3.3 *Devices ensuring protection against short-circuit current only*

A device providing protection against short-circuit current only shall be installed where overload protection is achieved by other means or where **4.4.4** permits overload protection to be dispensed with. Such a device shall be capable of breaking, and for a circuit-breaker making, the short-circuit current up to and including the prospective short-circuit current. Such a device shall satisfy the requirements of **4.4.4**.

Such devices may be:

a) circuit-breakers with short-circuit release only, and
b) fuses with gM, aM type fuse links.

4.4.3.4 *Characteristics of protective devices*

The operating characteristics of overcurrent protective devices shall comply with those specified in, for example, IS/IEC 60898, IS/IEC 60947-2, IS/IEC 60947-6-2, IS 12640 (Part 2), IS 13703 (Part 2), IEC 60269-3, IS 13730 (Part 4) or IS/IEC 60947-3.

NOTE — The use of other devices is not excluded provided that their time/current characteristics provide an equivalent level of protection to that specified in this clause.

4.4.4 *Protection Against Overload Current*

4.4.4.1 *Coordination between conductors and overload protective devices*

The operating characteristics of a device protecting a cable against overload shall satisfy the two following conditions:

$$I_B \leq I_n \leq I_Z \quad \text{... (1)}$$

$$I_2 \leq 1.45 \times I_Z \quad \text{... (2)}$$

where

I_B = the design current for that circuit;

I_Z = the continuous current-carrying capacity of the cable (*see* **5.2.6**);

I_n = the rated current of the protective device;

NOTE — For adjustable protective devices, the rated current I_n is the current setting selected.

I_2 = the current ensuring effective operation in the conventional time of the protective device.

The current I_2 ensuring effective operation of the protective device shall be provided by the manufacturer or as given in the product standard.

Protection in accordance with this clause may not ensure protection in certain cases, for example where sustained overcurrents less than I_2 occur. In such cases, consideration should be given to selecting a cable with a larger cross-sectional area.

NOTES

1 I_B is the design current through the line or the permanent current through neutral in case of a high level of the third harmonic.

2 The current ensuring effective operation in the conventional time of protective devices may also be named I_t or I_f according to the product standards. Both I_t and I_f are multiples of I_n and attention should be given to the correct representation of values and indexes.

3 *See* Annex E for an illustration of conditions (1) and (2) of **4.4.4.1**.

4 Design current I_B can be considered as an actual current I_a after applying correction factors, *see* **4.1.5.6.1**.

4.4.4.2 *Position of devices for overload protection*

4.4.4.2.1 A device ensuring protection against overload shall be placed at the point where a change, such as a change in cross-sectional area, nature, method of installation or in constitution, causes a reduction in the value of current-carrying capacity of the conductors, except where **4.4.4.2.2** and **4.4.4.3** apply.

4.4.4.2.2 The device protecting the conductor against overload may be placed along the run of that conductor if the part of the run between the point where a change occurs (in cross-sectional area, nature, method of installation or constitution) and the position of the protective device has neither branch circuits nor socket-outlet circuits and fulfils at least one of the following two conditions:

a) it is protected against short-circuit current in accordance with the requirements stated in **4.4.5**;
b) its length does not exceed 3 m, it is carried out in such a manner as to reduce the risk of short-circuit to a minimum, and it is installed in such a manner as to reduce to a minimum the risk of fire or danger to persons (*see also* **4.4.5.2.1**).

NOTE — For installation according to (a) *see* Fig. 69. For installation according to (b) *see* Fig. 70.

4.4.4.3 *Omission of devices for protection against overload*

The various cases stated in this sub-clause shall not be applied to installations situated in locations presenting a fire risk or risk of explosion or where the requirements for special installations and locations specify different conditions.

4.4.4.3.1 *General*

Devices for protection against overload need not be provided:

a) for a conductor situated on the load side of a change in cross-sectional area, nature, method of installation or in constitution, that is effectively protected against overload by a protective device placed on the supply side;
b) for a conductor that is not likely to carry overload current, provided that this conductor is protected against short-circuit in accordance with the requirements of **4.4.4** and that it has neither branch circuits nor socket-outlets;
c) at the origin of an installation where the distributor provides an overload device and agrees that it affords protection to the part of the installation between the origin and the main distribution point of the installation where further overload protection is provided.
d) for circuits for telecommunications, control, signalling and the like.

NOTE — For installations according to (a), (b) and (d), *see* Fig. 71.

4.4.4.3.2 *Position or omission of devices for protection against overload in IT systems*

4.4.4.3.2.1 The provisions in **4.4.4.2.2** and **4.4.4.3.1** for an alternative position or omission of devices for protection against overload are not applicable to IT systems unless each circuit not protected against overload is protected by one of the following means:

a) use of the protective measures described in **4.2.12**;
b) protection of each circuit by a residual current protective device that will operate immediately on a second fault; and
c) for permanently supervised systems only use of insulation monitoring which either:
   1) causes the disconnection of the circuit when the first fault occurs, or
   2) gives a signal indicating the presence of a fault. The fault shall be rectified according to the operational requirements and recognizing the risk from a second fault.

NOTE — It is recommended to install an insulation fault location system. With the application of such a system it is possible to

detect and locate the insulation fault without interruption of the supply.

4.4.4.3.2.2 In IT systems without a neutral conductor, the overload protective device may be omitted in one of the phase conductors if a residual current protective device is installed in each circuit.

4.4.4.3.3 *Cases where omission of devices for overload protection shall be considered for safety reasons*

The omission of devices for protection against overload is permitted for circuits supplying current-using equipment where unexpected disconnection of the circuit could cause danger or damage. Examples of such cases include:

a) exciter circuits of rotating machines;
b) supply circuits of lifting magnets;
c) secondary circuits of current transformers;
d) circuits which supply fire extinguishing devices; and
e) circuits supplying safety services (burglar alarm, gas alarms, etc).

NOTE — In such cases, consideration should be given to the provision of an overload alarm.

4.4.4.4 *Overload protection of conductors in parallel*

Where a single protective device protects several conductors in parallel, there shall be no branch circuits or devices for isolation or switching in the parallel conductors.

This subclause does not preclude the use of ring final circuits.

4.4.4.4.1 *Equal current sharing between parallel conductors*

Where a single device protects conductors in parallel sharing currents equally, the value of I_z to be used in **4.4.4.1** is the sum of the current-carrying capacities of the various conductors.

It is deemed that current sharing is equal if the requirements of the first indent of **5.2.6.7**(a) are satisfied.

4.4.4.4.2 *Unequal current sharing between parallel conductors*

Where the use of a single conductor, per phase, is impractical and the currents in the parallel conductors are unequal, the design current and requirements for overload protection for each conductor shall be considered individually.

NOTE — Currents in parallel conductors are considered to be unequal if the difference between any currents is more than 10 percent of the design current for each conductor. Guidance is given in **G-2.**

4.4.5 *Protection Against Short-Circuit Currents*

This standard only considers the case of short-circuit between conductors belonging to the same circuit.

4.4.5.1 *Determination of prospective short-circuit currents*

The prospective short-circuit current at every relevant point of the installation shall be determined. This may be carried out either by calculation or by measurement.

NOTE — The prospective short-circuit current at the supply point may be obtained from the supply utility.

4.4.5.2 *Position of devices for short-circuit protection*

A device ensuring protection against short-circuit shall be placed at the point where a reduction in the cross-sectional area of the conductors or another change causes a change to the current-carrying capacity of the conductors, except where **4.4.5.2.1**, **4.4.5.2.2** or **4.4.5.3** applies.

4.4.5.2.1 The various cases stated in the following sub clause shall not be applied to installations situated in locations presenting a fire risk or risk of explosion and where special rules for certain locations specify different conditions. The device for protection against short-circuit may be placed other than as specified in **4.4.4.2**, under the following conditions.

In the part of the conductor between the point of reduction of cross-sectional area or other change and the position of the protective device there shall be no branch circuits nor socket-outlet circuits and that part of the conductor shall:

a) not exceed 3 m in length, and
b) be installed in such a manner as to reduce the risk of a short-circuit to a minimum, and

NOTE — This condition may be obtained for example by reinforcing the protection of the wiring against external influences (*see* Fig. 73).

c) not be placed close to combustible material.

4.4.5.2.2 A protective device may be placed on the supply side of the reduced cross-sectional area or another change made, provided that it possesses an operating characteristic such that it protects the wiring situated on the load side against short-circuit, in accordance with **4.4.5.5.2**.

NOTE — The requirements of **4.4.4.2.2** may be met by the method given in Annex G.

4.4.5.3 *Omission of devices for protection against short-circuit*

Provided that both of the following conditions are

simultaneously fulfilled:

- the wiring is installed in such a way as to reduce the risk of a short-circuit to a minimum{*see* item b) of **4.4.5.2.1**}, and
- the wiring is not placed close to combustible material, devices for protection against short-circuit need not be provided for applications such as:
  a) conductors connecting generators, transformers, rectifiers, accumulator batteries to the associated control panels, the protective devices being placed in these panels;
  b) circuits where disconnection could cause danger for the operation of the installations concerned, such as those cited in **4.4.4.3.3**;
  c) certain measuring circuits;
  d) at the origin of an installation where the distributor installs one or more devices providing protection against short-circuit and agrees that such a device affords protection to the part of the installation between the origin and the main distribution point of the installation where further short-circuit protection is provided.

4.4.5.4 *Short-circuit protection of conductors in parallel*

A single protective device may protect conductors in parallel against the effects of short-circuit provided that the operating characteristics of that device ensures its effective operation should a fault occur at the most onerous position in one of the parallel conductors. Account shall be taken of the sharing of the short-circuit currents between the parallel conductors. A fault can be fed from both ends of a parallel conductor.

If operation of a single protective device is not effective, then one or more of the following measures shall be taken:

a) The wiring shall be carried out in such a way as to reduce to a minimum the risk of a short-circuit in any parallel conductor, for example, by protection against mechanical damage, and conductors shall be installed in such a manner as to reduce to a minimum the risk of fire or danger to persons.
b) For two conductors in parallel, a short-circuit protective device shall be provided at the supply end of each parallel conductor.
c) For more than two conductors in parallel, short-circuit protective devices shall be provided at the supply and load ends of each parallel conductor.

Guidance is given in **G-3**.

4.4.5.5 *Characteristics of short-circuit protective devices*

Each short-circuit protective device shall meet the requirements given in **4.4.5.5.1**.

4.4.5.5.1 The rated breaking capacity shall be not less than the prospective maximum short-circuit current at the place of its installation, except where the following paragraph applies.

A lower rated breaking capacity is permitted if another protective device having the necessary breaking capacity is installed on the supply side. In that case, the characteristics of the devices shall be coordinated so that the energy let through by these two devices does not exceed that which can be withstood without damage by the device on the load side and the conductors protected by these devices.

NOTE — In certain cases other characteristics may need to be taken into account such as dynamic stresses and arcing energyfor the device on the load side. Details of the characteristics needing coordination should be obtained from the manufacturers of the devices concerned.

4.4.5.5.2 For cables and insulated conductors, all current caused by a short-circuit occurring at any point of the circuit shall be interrupted in a time not exceeding that which brings the insulation of the conductors to the permitted limit temperature.

For operating times of protective devices <0.1 s where asymmetry of the current is of importance and for current-limiting devices k^2S^2 shall be greater than the value of the let-through energy (I^2t) quoted by the manufacturer of the protective device.

For short-circuits of duration up to 5 s, the time t, in which a given short-circuit current will raise the insulation of the conductors from the highest permissible temperature in normal duty to the limit temperature can, as an approximation, be calculated from the formula:

$$t = (k \times S/I)^2 \qquad \text{... (3)}$$

where

t	=	the duration, in s;
S	=	the cross-sectional area, in mm^2;
I	=	the effective short-circuit current, in A, expressed as an r.m.s. value; and
k	=	a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures. For common conductor insulation, the values of k for line conductors are shown in Table 3.

Table 3 Values of *k* for Conductors

(*Clause* 4.4.5.5.2)

Property/Condition	**Type of Conductor Insulation**							
	PVC Thermoplastic		PVC Thermoplastic 90°C		EPR XLPE Thermosetting	Rubber 60 °C Thermosetting	Mineral	
							PVC sheathed	Bare unsheathed
Conductor cross-sectional area mm²	≤ 300	> 300	≤ 300	> 300				
Initial temperature °C	70		90		90	60	70	105
Final temperature °C	160	140	160	140	250	200	160	250
Conductor material:								
Copper	115	103	100	86	143	141	115	135-115[1)]
Aluminium	76	68	66	57	94	93	–	–
Tin-soldered joints in copper conductors	115	–	–	–	–	–	–	–

[1)] This value shall be used for bare cables exposed to touch.

NOTES

1 Other values of *k* are under consideration for:

– small conductors (particularly for cross-sectional areas less than 10 mm²);

– other types of joints in conductors;

– bare conductors.

2 The nominal current of the short-circuit protective device may be greater than the current-carrying capacity of the cable.

3 The above factors are based on IEC 60724.

4 *See* Annex EE (**5.4**) for the calculation-method of factor *k*.

4.4.5.5.3 For busbar trunking systems complying with IEC 61439-2 and powertrack complying with the IEC 61534 series, one of the following requirements shall apply:

a) The rated short-time withstand current (I_{CW}) and the rated peak withstand current of a busbar trunking or powertrack system shall not be lower than the prospective short-circuit current r.m.s. value and the prospective short-circuit peak current value, respectively. The maximum time for which the I_{CW} is defined for the busbar trunking or powertrack system shall not be less than the maximum operating time of the protective device.

b) The rated conditional short-circuit current of the busbar trunking or powertrack system associated with a specific protective device, shall not be lower than the prospective short-circuit current.

4.4.6 *Coordination of Overload and Short-Circuit Protection*

4.4.6.1 *Protection afforded by one device*

A protective device providing protection against overload and short-circuit currents shall fulfil the applicable requirements of **4.4.4** and **4.4.5**.

4.4.6.2 *Protection Afforded by Separate Devices*

The requirements of **4.4.4** and **4.4.5** apply, respectively, to the overload protective device and the short-circuit protective device.

The characteristics of the devices shall be coordinated so that the energy let through by the short-circuit protective device does not exceed that which can be withstood without damage by the overload protective device.

NOTE — This requirement does not exclude the type of coordination specified in IS/ IEC 60947-4-1.

4.4.7 *Limitation of overcurrent by characteristics of supply*

Conductors are considered to be protected against overload and short-circuit currents where they are supplied from a source incapable of supplying a current exceeding the current-carrying capacity of the conductors (for example, certain bell transformers, certain welding transformers and certain types of thermoelectric generating sets).

4.5 Protection for Safety — Protection Against Voltage Disturbance and Electromagnetic Disturbance

4.5.1 *Void*

4.5.2 *Protection of Low-voltage Installations against Temporary Overvoltages Due to Earth Faults in the*

High-voltage System and Due to Faults in the Low-voltage System

4.5.2.1 *Field of application*

The rules of this clause provide requirements for the safety of low-voltage installation in the event of:

a) a fault between the high-voltage system and earth in the transformer substation that supplies the low-voltage installation,
b) a loss of the supply neutral in the low-voltage system,
c) a short-circuit between a line conductor and neutral, and
d) an accidental earthing of a line conductor of a low-voltage IT-system.

The requirements for the earthing arrangement at the transformer substation are given in IEC 61936-1.

4.5.2.1.1 *General requirements*

As **4.5.2** covers faults between a high-voltage line and the earth in the HV/LV substation, it gives rules for the designer and installer of the substation. It is necessary to have the following information concerning the high-voltage system:

a) quality of the system earthing;
b) maximum level of earth fault current; and
c) resistance of the earthing arrangement.

The following subclauses consider four situations as proposed in **4.5.2.1**, which generally cause the most severe temporary overvoltages such as defined in IS 1885 (Part 70):

a) fault between the high-voltage system(s) and earth (*see* **4.5.2.2**);
b) loss of the neutral in a low-voltage system (*see* **4.5.2.3**);
c) accidental earthing of a low-voltage IT system (*see* **4.5.2.4**); and
d) short-circuit in the low-voltage installation (*see* **4.5.2.5**).

4.5.2.1.2 *Symbols*

In **4.5.2** the following symbols are used (*see* Fig. 27):

I_E part of the earth fault current in the high-voltage system that flows through the earthing arrangement of the transformer substation.

R_E resistance of the earthing arrangement of the transformer substation.

R_A resistance of the earthing arrangement of the exposed-conductive-parts of the equipment of the low-voltage installation.

R_B resistance of the earthing arrangement of the low-voltage system neutral, for low-voltage systems in which the earthing arrangements of the transformer substation and of the low-voltage system neutral are electrically independent.

U_o *in TN- and TT-systems*: nominal a.c. r.m.s. line voltage to earth

in IT-systems: nominal a.c. voltage between line conductor and neutral conductor or midpoint conductor, as appropriate.

U_f power-frequency fault voltage that appears in the low-voltage system between exposed-conductive-parts and earth for the duration of the fault.

U_1 power-frequency stress voltage between the line conductor and the exposed-conductive-parts of the low-voltage equipment of the transformer substation during the fault.

U_2 power-frequency stress voltage between the line conductor and the exposed-conductive-parts of the low-voltage equipment of the low-voltage installation during the fault.

NOTE — The power-frequency stress voltage (U_1 and U_2) is the voltage that appears across the insulation of low-voltage equipment and across surge protective devices connected to the low-voltage system.

The following additional symbols are used in respect of IT-systems in which the exposed conductive parts of the equipment of the low-voltage installation are connected to an earthing arrangement that is electrically independent of the earthing arrangement of the transformer substation.

I_h fault current that flows through the earthing arrangement of the exposed-conductive-parts of the equipment of the low-voltage installation during a period when there is a high-voltage fault and a first fault in the low-voltage installation (*see* Table 4).

Id fault current, in accordance with **4.2.11.6.2**, that flows through the earthing arrangement of the exposed-conductive-parts of the low-voltage installation during the first fault in a low-voltage system (*see* Table 4).

Z impedance (for example IMD internal impedance, artificial neutral impedance) between the low-voltage system and an earthing arrangement.

NOTE — An earthing arrangement may be considered electrically independent of another earthing arrangement if a rise of potential with respect to earth in one earthing arrangement does not cause an unacceptable rise of potential with respect to earth in the other earthing arrangement (*see* IEC 61936-1).

4.5.2.2 *Overvoltages in LV-systems during a high-voltage earth fault*

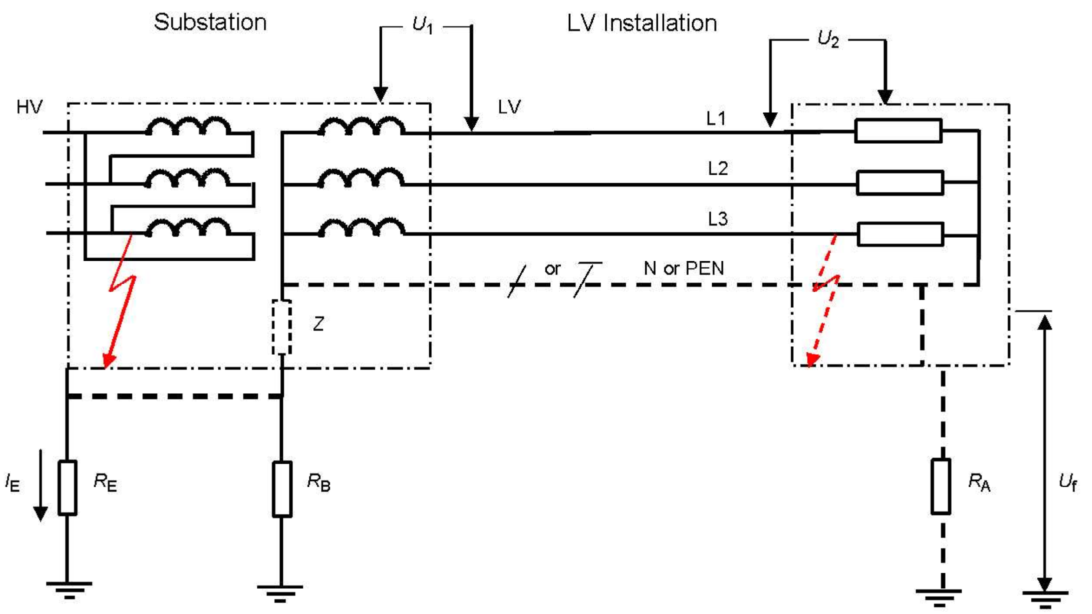


FIG. 27 REPRESENTATIVE SCHEMATIC SKETCH FOR POSSIBLE CONNECTIONS TO EARTHING SUBSTATION AND LV-INSTALLATION AND OCCURRING OVERVOLTAGES IN CASE OF FAULTS

In case of a fault to earth on the HV-side of the substation, the following types of overvoltage may affect the LV-installation:

a) power frequency fault-voltage (U_f);
b) power frequency stress-voltages (U_1 and U_2).

Table 4 provides the relevant methods of calculation for the different types of overvoltages.

NOTE — Table 4 deals with IT systems with a neutral point only. For IT systems with no neutral point, the formulae should be adjusted accordingly.

Where high- and low-voltage earthing systems exist in proximity to each other, two practices are presently used:

— interconnection of all high-voltage (R_E) and low-voltage (R_B) earthing systems; and
— separation of high-voltage (R_E) from low-voltage (R_B) earthing systems.

The general method used is interconnection. The high- and low-voltage earthing systems shall be interconnected if the low-voltage system is totally confined within the area covered by the high-voltage earthing system (*see* IEC 61936-1).

NOTE — Details of the different types of system earthing (TN, TT, IT) are shown in National Electrical Code 2011 and IS 3043.

4.5.2.2.1 *Magnitude and duration of power-frequency fault voltage*

The magnitude and the duration of the fault voltage U_f (as calculated in Table 4) which appears in the LV installation between exposed conductive parts and earth, shall not exceed the values given for U_f by the curve of Fig. 28 for the duration of the fault.

Normally, the PEN conductor of the low-voltage system is connected to earth at more than one point. In this case, the total resistance is reduced. For these multiple grounded PEN conductors, U_f can be calculated as:

$$U_f = 0.5\ R_E \times I_E$$

NOTE — The curve shown in Fig. 28 is taken from IEC 61936-1. On the basis of probabilistic and statistical evidence this curve represents a low level of risk for the simple worst case where the low voltage system neutral conductor is earthed only at the transformer substation earthing arrangements.

4.5.2.2.2 *Magnitude and duration of power-frequency stress voltages*

The magnitude and the duration of the power-frequency stress voltage (U_1 and U_2) as calculated in Table 4 of the low-voltage equipment in the low-voltage installation due to an earth fault in the high-voltage system shall not exceed the requirements given in Table 5.

4.5.2.2.3 *Requirements for calculation of limits*

Where required by Table 4, the permissible power-frequency stress voltage shall not exceed the value given in Table 5.

Where required by Table 4, the permissible power-frequency fault voltage shall not exceed the value given in Table 5.

Table 4 Power-Frequency Stress Voltages and Power-Frequency Fault Voltage in Low-Voltage System
(*Clauses* 4.5.2.2 *and* 4.5.2.2.2).

Types of System Earthing	Types of Earth Connections	U_1	U_2	U_f
(1)	(2)	(3)	(4)	(5)
TT	R_E and R_B connected	U_o	$R_E \times I_E + U_o$	0 [1)]
	R_E and R_B separated	$R_E \times I_E + U_o$	U_o [1)]	0 [1)]
TN	R_E and R_B connected	U_o [1)]	U_o [1)]	$R_E \times I_E$ [2)]
	R_E and R_B separated	$R_E \times I_E + U_o$	U_o [1)]	0 [1)]
IT	R_E and Z connected R_E and R_A separated	U_o [1)]	$R_E \times I_E + U_o$	0 [1)]
		$U_o \times \sqrt{3}$	$R_E \times I_E + U_o \times \sqrt{3}$	$R_A \times I_h$
	R_E and Z connected R_E and R_A interconnected	U_o [1)]	U_o [1)]	$R_E \times I_E$
		$U_o \times \sqrt{3}$	$U_o \times \sqrt{3}$	$R_E \times I_E$
	R_E and Z separated R_E and R_A separated	$R_E \times I_E + U_o$	U_o [1)]	0 [1)]
		$R_E \times I_E + U_o \times \sqrt{3}$	$U_o \times \sqrt{3}$	$R_A \times I_d$

[1)] No consideration needs to be given.
[2)] *See* **4.3.2.2.1** second paragraph.
With existing earth fault in the installation.

NOTES

1 The requirements for U_1 and U_2 are derived from design criteria for insulation of low-voltage equipment with regard to temporary power-frequency overvoltage (*see also* Table 4).

2 In a system whose neutral is connected to the earthing arrangement of the transformer substation, such temporary power-frequency overvoltage is also to be expected across insulation which is not in an earthed enclosure when the equipment is outside a building.

3 In TT- and TN-systems the statement "connected" and "separated" refers to the electrical connection between R_E and R_B. For IT-systems it refers to the electrical connection between R_E and Z and the connection between R_E and R_A.

Table 5 Permissible Power-Frequency Stress Voltage
(*Clause* 4.5.2.2.2)

Duration of the Earth Fault in the High-Voltage System t	Permissible Power-Frequency Stress Voltage on Equipment in Low-Voltage Installations U
>5 s 5 s	U_o + 250 V U_o + 1 200 V

In systems without a neutral conductor, U_o shall be the line-to-line voltage.

NOTES

1 The first line of the table relates to high-voltage systems having long disconnection times, for example, isolated neutral and resonant earthed high-voltage systems. The second line relates to high-voltage systems having short disconnection times, for example low-impedance earthed high-voltage systems. Both lines together are relevant design criteria for insulation of low-voltage equipment with regard to temporary power frequency overvoltage, IS 15382 (Part 1).

2 In a system whose neutral is connected to the earthing arrangement of the transformer substation, such temporary power-frequency overvoltage is also to be expected across insulation which is not in an earthed enclosure when the equipment is outside a building.

The requirements of **4.3.2.2.2** and **4.3.2.2.3** are deemed to be fulfilled for installations receiving a supply at low-voltage from a public electricity distribution system.

To fulfil the above requirements, coordination between the HV-system operator and the LV-system installer is necessary. Compliance with the above requirements mainly falls into the responsibility of the substation installer/owner/operator who needs also to fulfil requirements provided by IEC 61936-1. Therefore the calculation for U_1, U_2 and U_f is normally not necessary for the LV system installer.

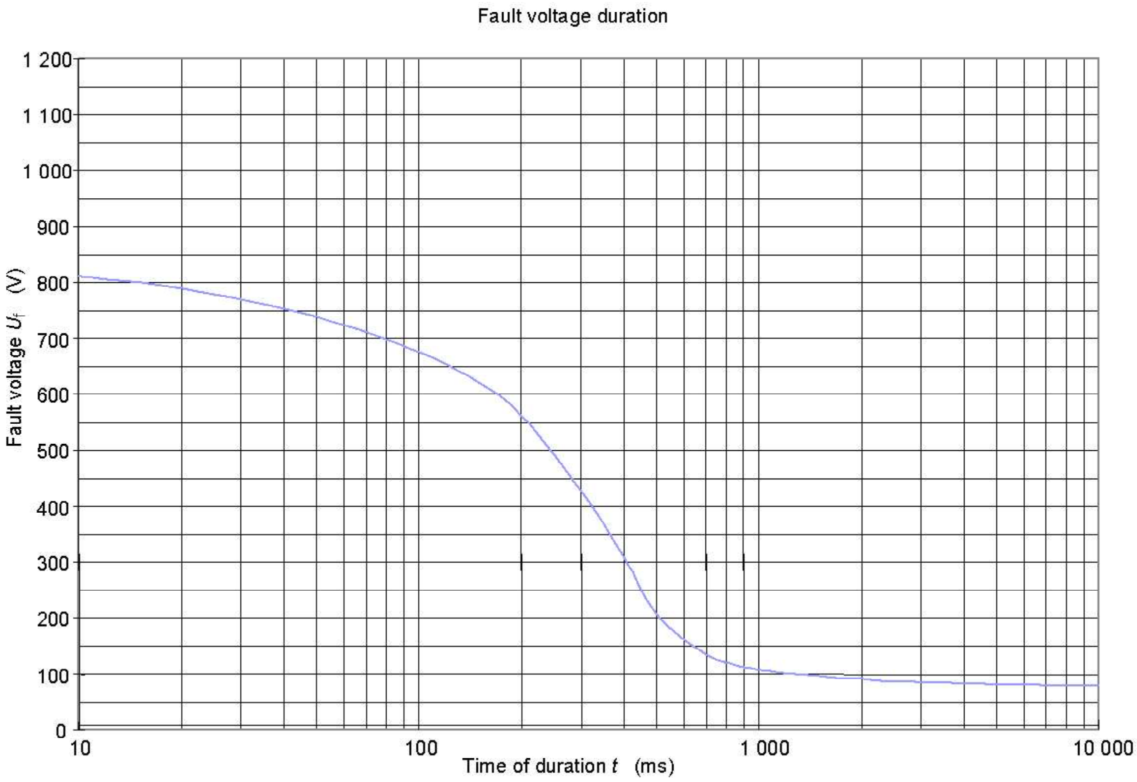


FIG. 28 TOLERABLE FAULT VOLTAGE DUE TO AN EARTH-FAULT IN THE HV SYSTEM

Possible measures to fulfil the above requirements are, for example

a) separation of earthing arrangement between HV and LV;
b) change of LV system earthing; and
c) reduction of earth resistance R_E.

4.5.2.3 *Power-frequency stress voltage in case of loss of the neutral conductor in a TN and TT system*

Consideration shall be given to the fact that, if the neutral conductor in a multi-phase system is interrupted, basic, double and reinforced insulation as well as components rated for the voltage between line and neutral conductors can be temporarily stressed with the line-to-line voltage. The stress voltage can reach up to $U = \sqrt{3}\ U_o$.

4.5.2.4 *Power-frequency stress voltage in the event of an earth fault in an IT system with distributed neutral*

Consideration shall be given to the fact that, if a line conductor of an IT system is earthed accidentally, insulation or components rated for the voltage between line and neutral conductors can be temporarily stressed with the line-to-line voltage. The stress voltage can reach up to $U = \sqrt{3}\ U_o$.

4.5.2.5 *Power-frequency stress voltage in the event of a short-circuit between a line conductor and the neutral conductor*

Consideration shall be given to the fact that if a short-circuit occurs in the low-voltage installation between a phase conductor and the neutral conductor, the voltage between the other line conductors and the neutral conductor can reach the value of $1.45 \times U_o$ for a time up to 5 s.

4.5.3 *Protection Against Overvoltages of Atmospheric Origin or Due to Switching*

4.5.3.1 *General*

This clause deals with protection of electrical installations against transient overvoltages of atmospheric origin transmitted by the supply distribution system and against switching overvoltages.

In general, switching overvoltages are lower than overvoltages of atmospheric origin and, therefore, the requirements regarding protection against overvoltages of atmospheric origin normally cover protection against switching overvoltages.

NOTE — Statistical evaluations of measurements have shown that there is a low risk of switching overvoltages higher than the level of overvoltage category II (*see* **4.5.3.2**).

Consideration shall be given to the overvoltages which can appear at the origin of an installation, to the expected keraunic level and to the location and characteristics of

surge protective devices, so that the probability of incidents due to overvoltage stresses is reduced to an acceptable level for the safety of persons and property, as well as for the continuity of service desired.

The values of transient overvoltages depend on the nature of the supply distribution system (underground or overhead) and the possible existence of a surge protective device upstream of the origin of the installation and the voltage level of the supply system.

This clause provides guidance where protection against overvoltages is covered by inherent control or assured by protective control. If the protection according to this clause is not provided, insulation co-ordination is not assured and the risk due to overvoltages shall be evaluated.

This clause does not apply in case of overvoltages due to direct or nearby lightning. For protection against transient overvoltages due to direct lightning, IS/IEC 62305-1, IS/IEC 62305-3, IS/IEC 62305-4 and the IS/IEC 61643 series are applicable. This clause does not cover overvoltage through data-transmission systems.

NOTES

1 As regards transient atmospheric overvoltages, no distinction is made between earthed and unearthed systems.

2 Switching overvoltages generated outside the installation and transmitted by the supply network are under consideration.

4.5.3.2 *Classification of impulse withstand voltages (overvoltage categories)*

4.5.3.2.1 *Purpose of classification of impulse withstand voltages (overvoltage categories)*

NOTES

1 Overvoltage categories are defined within electrical installations for the purpose of insulation co-ordination and a related classification of equipment with impulse withstand voltages is provided (*see* Table 6).

2 The rated impulse withstand voltage is an impulse withstand voltage assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against overvoltages [in accordance with IS 15382 (Part 1)].

The impulse withstand voltage (overvoltage category) is used to classify equipment energized directly from the mains.

Impulse withstand voltages for equipment selected according to the nominal voltage are provided to distinguish different levels of availability of equipment with regard to continuity of service and an acceptable risk of failure. By selection of equipment with a classified impulse withstand voltage, insulation co-ordination can be achieved in the whole installation, reducing the risk of failure to an acceptable level.

NOTE — Transient overvoltages transmitted by the supply distribution system are not significantly attenuated down stream in most installations.

4.5.3.2.2 *Relationship between impulse withstand voltages of equipment and overvoltage categories*

Equipment with an impulse withstand voltage corresponding to overvoltage category IV is suitable for use at, or in the proximity of, the origin of the installation, for example, upstream of the main distribution board. Equipment of category IV has a very high impulse withstand capability providing the required high degree of reliability.

NOTE — Examples of such equipment are electricity meters, primary overcurrent protection devices and ripple control units.

Equipment with an impulse withstand voltage corresponding to overvoltage category III is for use in the fixed installation downstream of, and including the main distribution board, providing a high degree of availability.

NOTE — Examples of such equipment are distribution boards, circuit-breakers, wiring systems (*see* IEC 60050-826, definition 826-15-01), including cables, bus-bars, junction boxes, switches, socket-outlets) in the fixed installation, and equipment for industrial use and some other equipment, for example stationary motors with permanent connection to the fixed installation.

Equipment with an impulse withstand voltage corresponding to overvoltage category II is suitable for connection to the fixed electrical installation, providing a normal degree of availability normally required for current-using equipment.

NOTE — Examples of such equipment are household appliances and similar loads.

Equipment with an impulse withstand voltage corresponding to overvoltage category I is only suitable for use in the fixed installation of buildings where protective means are applied outside the equipment – to limit transient overvoltages to the specified level.

NOTE — Examples of such equipment are those containing electronic circuits like computers, appliances with electronic programmes, etc.

Equipment with an impulse withstand voltage corresponding to overvoltage category I shall not have direct connection to a public supply system.

4.5.3.3 *Arrangements for overvoltage control*

Overvoltage control is arranged in accordance with the following requirements.

4.5.3.3.1 *Inherent overvoltage control*

This sub-clause does not apply when a risk assessment according to **4.5.3.3.2.2** is used.

Where an installation is supplied by a completely buried low-voltage system and does not include overhead lines, the impulse withstand voltage of equipment in accordance with Table 6 is sufficient and no specific protection against overvoltages of atmospheric origin is necessary.

NOTE — A suspended cable having insulated conductors with earthed metallic screen is considered as equivalent to an underground cable.

Where an installation is supplied by or includes a low-voltage overhead line and the keraunic level is lower than or equal to 25 days per year (AQ 1), no specific protection against overvoltages of atmospheric origin is required.

NOTE — Irrespective of the AQ value, protection against overvoltages may be necessary in applications where a higher reliability or higher risks (for example, fire) are expected.

In both cases, consideration regarding protection against transient overvoltages shall be given to equipment with an impulse withstand voltage according to overvoltage category I (*see* **4.5.3.2.2**).

4.5.3.3.2 *Protective overvoltage control*

In all cases, consideration regarding protection against transient over voltages shall be given to equipment with an impulse withstand voltage according to overvoltage category I (*see* **4.5.3.2.2**).

4.5.3.3.2.1 *Protective overvoltage control based on conditions of external influences*

Where an installation is supplied by, or includes, an overhead line, and the keraunic level of the location is greater than 25 days per year (AQ 2), protection against overvoltages of atmospheric origin is required. The protection level of the protective device shall not be higher than the level of overvoltage category II, given in Table 6.

NOTES

1 The overvoltage level may be controlled by surge protective devices applied close to the origin of the installation, either in the overhead lines (*see* Annex B) or in the building installation.

2 According to **A.1** of IS/ IEC 62305-3, 25 thunderstorm days per year are equivalent to a value of 2.5 flashes per km^2 per year. This is derived from the formula

$$N_g = 0.1\ T_d$$

where

N_g = the frequency of flashes per km^2 per year; and

T_d = the number of thunderstorm days per year (keraunic level).

4.5.3.3.2.2 *Protective overvoltage control based on risk assessment*

NOTE — A method of general risk assessment is described in IEC 61662. As far as **4.5.3** is concerned, an essential simplification of this method has been accepted. It is based on the critical length d_C of the incoming lines and the level of consequences as described below.

The following are different consequential levels of protection:

a) consequences related to human life, for example, safety services, medical equipment in hospitals;
b) consequences related to public services, for example, loss of public services, IT centres, museums;
c) consequences to commercial or industrial activity, for example, hotels, banks, industries, commercial markets, farms;
d) consequences to groups of individuals, for example, large residential buildings, churches, offices, schools; and
e) consequences to individuals, for example, residential buildings, small offices.

For levels of consequences (a) to (c), protection against overvoltage shall be provided.

NOTE — There is no need to perform a risk assessment calculation according to Annex K for levels of consequences (a) to (c) because this calculation always leads to the result that the protection is required.

For levels of consequences (d) and (e), requirement for protection depends on the result of a calculation. The calculation shall be carried out using the formula in Annex K for the determination of the length *d*, which is based on a convention and called conventional length.

Protection is required if:

$$d > d_c$$

where

d = the conventional length in km of the supply line of the considered structure with a maximum value of 1 km;

d_c = the critical length;

d_c in km = equal to $\frac{1}{N_g}$ for level of consequences (d)

and equal to $\frac{2}{N_g}$ for level of consequences (e) where N_g is the frequency of flashes per km^2 per year.

If this calculation indicates that an SPD is required, the protection level of these protective devices shall not be higher than the level of overvoltage category II, given in Table 6.

4.5.3.4 *Required impulse withstand voltage of equipment*

Equipment shall be selected so that its rated impulse withstand voltage is not less than the required impulse withstand voltage as specified in Table 6. It is the responsibility of each product committee to require the rated impulse withstand voltage in their relevant standards according to IEC 60664-1.

4.5.4 *Measures Against Electromagnetic Influences*

4.5.4.1 *General*

The **4.5.4** provides basic recommendations for the mitigation of electromagnetic disturbances.

Table 6 Required Rated Impulse Withstand Voltage of Equipment
(*Clauses* 4.5.3.2.1, 4.5.3.3.1, 4.5.3.3.2.1 *and* 4.5.3.4)

Nominal voltage of the installation[1)] V		**Required Impulse Withstand Voltage For** kV[3)]			
Three-phase Systems[2)]	Single-phase Systems with Middle Point	Equipment at the Origin of the Installation (Overvoltage Category IV)	Equipment of Distribution and Final Circuits (Overvoltage Category III)	Appliances and Current-using Equipment (Overvoltage Category II)	Specially Protected Equipment (Overvoltage Category I)
–	120-240	4	2.5	1.5	0.8
230/400[2)] 277/480[2)]	–	6	4	2.5	1.5
400/690	–	8	6	4	2.5
1 000	–	12	8	6	4

[1)] According to IEC 60038.
[2), 3)] This impulse withstand voltage is applied between live conductors and PE.

Electromagnetic Interference (EMI) may disturb or damage information technology systems or information technology equipment as well as equipment with electronic components or circuits. Currents due to lightning, switching operations, short-circuits and other electromagnetic phenomena may cause overvoltages and electromagnetic interference.

These effects are most severe

a) where large metal loops exist; and
b) where different electrical wiring systems are installed in common routes, for example, for power supply and for signalling information technology equipment within a building.

The value of the induced voltage depends on the rate of rise (d*i*/d*t*) of the interference current, and on the size of the loop.

Power cables carrying large currents with a high rate of rise of current (d*i*/d*t*) (for example, the starting current of lifts or currents controlled by rectifiers) can induce overvoltages in cables of information technology systems, which can influence or damage information technology equipment or similar electrical equipment.

In or near rooms for medical use, electric or magnetic fields associated with electrical installations can interfere with medical electrical equipment.

This clause provides information for architects of buildings and for designers and installers of electrical installations of buildings on some installation concepts that limit electromagnetic influences. Basic considerations are given here to mitigate such influences that may result in disturbance.

4.5.4.2 *Void*

4.5.4.3 *Definitions* (*see* **3**).

4.5.4.4 *Mitigation of electromagnetic interference* (*EMI*)

Consideration shall be given by the designer and installer of the electrical installation to the measures described below for reducing the electric and magnetic influences on electrical equipment.

Only electrical equipment, which meets the requirements in the appropriate EMC standards or the EMC requirements of the relevant product standard shall be used.

4.5.4.4.1 *Sources of EMI*

Electrical equipment sensitive to electromagnetic influences should not be located close to potential sources of electromagnetic emission such as:

a) switching devices for inductive loads,
b) electric motors,
c) fluorescent lighting,
d) welding machines,
e) computers,
f) rectifiers,
g) choppers,
h) frequency converters/regulators,
j) lifts,
k) transformers,
m) switchgear, and
n) power distribution busbars.

4.5.4.4.2 *Measures to reduce EMI*

The following measures reduce electromagnetic interference:

a) For electrical equipment sensitive to electromagnetic influences, surge protection devices and/or filters are recommended to improve electromagnetic compatibility with regard to conducted electromagnetic phenomena.
b) Metal sheaths of cables should be bonded to the CBN.

c) Inductive loops should be avoided by selection of a common route for power, signal and data circuits wiring.

d) Power and signal cables should be kept separate and should, wherever practical, cross each other at right-angles (*see* **4.5.4.6.3**).

e) Use of cables with concentric conductors to reduce currents induced into the protective conductor.

f) Use of symmetrical multicore cables (for example, screened cables containing separate protective conductors) for the electrical connections between convertors and motors, which have frequency controlled motor-drives.

g) Use of signal and data cables according to the EMC requirements of the manufacturer's instructions.

h) Where a lightning protection system is installed,

   1) power and signal cables shall be separated from the down conductors of lightning protection systems (LPS) by either a minimum distance or by use of screening. The minimum distance shall be determined by the designer of the LPS in accordance with IS/IEC 62305-3; and

   2) metallic sheaths or shields of power and signal cables should be bonded in accordance with the requirements for lightning protection given in IS/IEC 62305-3 and IS/IEC 62305-4.

j) Where screened signal or data cables are used, care should be taken to limit the fault current from power systems flowing through the screens and cores of signal cables, or data cables, which are earthed. Additional conductors may be necessary, for example, a by-pass equipotential bonding conductor for screen reinforcement (*see* Fig. 29).

NOTE — The provision of a by-pass conductor in proximity to a signal, or data, cable sheath also reduces the area of the loop associated with equipment, which is only connected by a protective conductor to earth. This practice considerably reduces the EMC effects of lightning electromagnetic pulse (LEMP).

k) Where screened signal cables or data cables are common to several buildings supplied from a TT-system, a by-pass equipotential bonding conductor should be used (*see* Fig. 30), The by-pass conductor shall have a minimum cross-sectional area of 16 mm^2 Cu or equivalent. The equivalent cross-sectional area shall be dimensioned in accordance with **5.4.4.1**.

NOTES

1 Where the earthed shield is used as a signal return path, a double-coaxial cable may be used.

2 It is recalled that if the consent according to **4.2.13.1.2** cannot be obtained, it is the responsibility of the owners or operators to avoid any danger due to the exclusion of those cables from the connection to the main equipotential bonding.

3 The problems of earth differential voltages on large public telecommunication networks are the responsibility of the network operator, who may employ other methods.

m) Equipotential bonding connections should have an impedance as low as possible

   – by being as short as possible,

   – by having a cross-section shape that results in low inductive reactance and impedance per metre of route, for example, a bonding braid with a width to thickness ratio of five to one.

n) Where an earthing busbar is intended (according to **4.5.4.5.7**) to support the equipotential bonding system of a significant information technology installation in a building, it may be installed as a closed ring.

NOTE — This measure is preferably applied in buildings of the telecommunications industry.

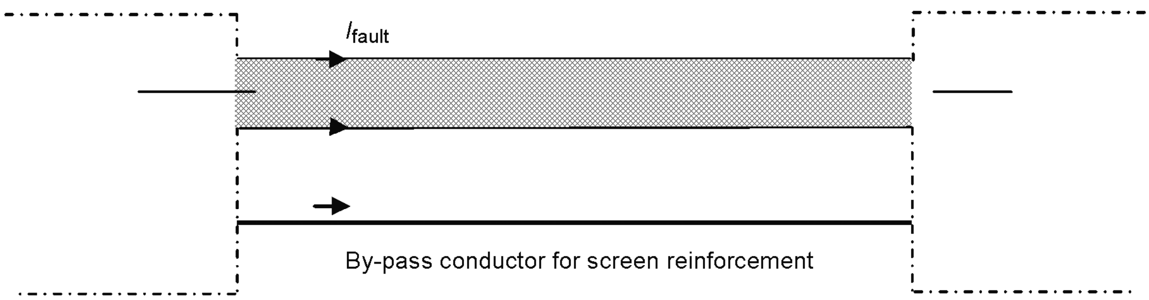


FIG. 29 BY-PASS CONDUCTOR FOR SCREEN REINFORCEMENT TO PROVIDE A COMMON EQUIPOTENTIAL BONDING SYSTEM

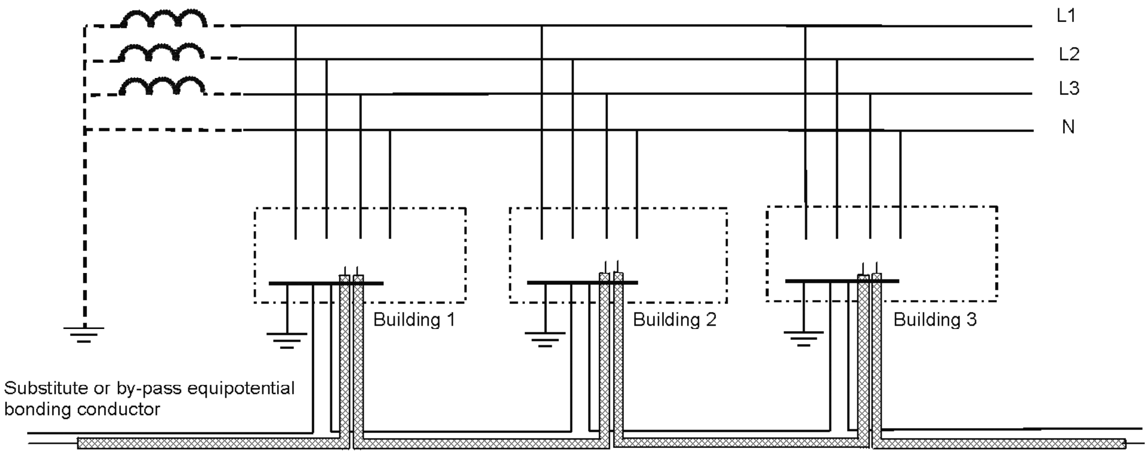


FIG. 30 EXAMPLE OF A SUBSTITUTE OR BY-PASS EQUIPOTENTIAL BONDING CONDUCTOR IN A TT-SYSTEM

4.5.4.4.3 *TN-system*

To minimize electromagnetic influences, the following sub-clauses apply.

4.5.4.4.3.1 It is recommended that TN-C systems should not be maintained in existing buildings containing, or likely to contain, significant amounts of information technology equipment.

TN-C-systems shall not be used in newly constructed buildings containing, or likely to contain, significant amounts of information technology equipment.

NOTE — Any TN-C installation is likely to have load or fault current diverted via equipotential bonding into metallic services and structures within a building.

4.5.4.4.3.2 In existing buildings supplied from public low-voltage networks and which contain, or are likely to contain, significant amounts of information technology equipment, a TN-S system should be installed downstream of the origin of the installation (*see* Fig. 31).

In newly constructed buildings, TN-S systems shall be installed downstream of the origin of the installation (*see* Fig. 31).

NOTE — The effectiveness of a TN-S-system may be enhanced by use of a residual current monitoring device, RCM.

4.5.4.4.3.3 In existing buildings where the complete low-voltage installation including the transformer is operated only by the user and which contain, or are likely to contain, significant amounts of information technology equipment, TN-S systems should be installed (*see* Fig. 32).

4.5.4.4.3.4 Where an existing installation is a TN-C-S system (*see* Fig. 33), signal and data cable loops should be avoided by

a) changing all TN-C parts of the installation shown in Fig. 33 into TN-S, as shown in Fig. 31, or
b) where this change is not possible, by avoiding signal and data cable interconnections between different parts of the TN-S installation.

4.5.4.4.4 *TT system*

In a TT system, such as that shown in Fig. 34, consideration should be given to overvoltages which may exist between live parts and exposed-conductive-parts when the exposed-conductive-parts of different buildings are connected to different earth electrodes.

4.5.4.4.5 *IT system*

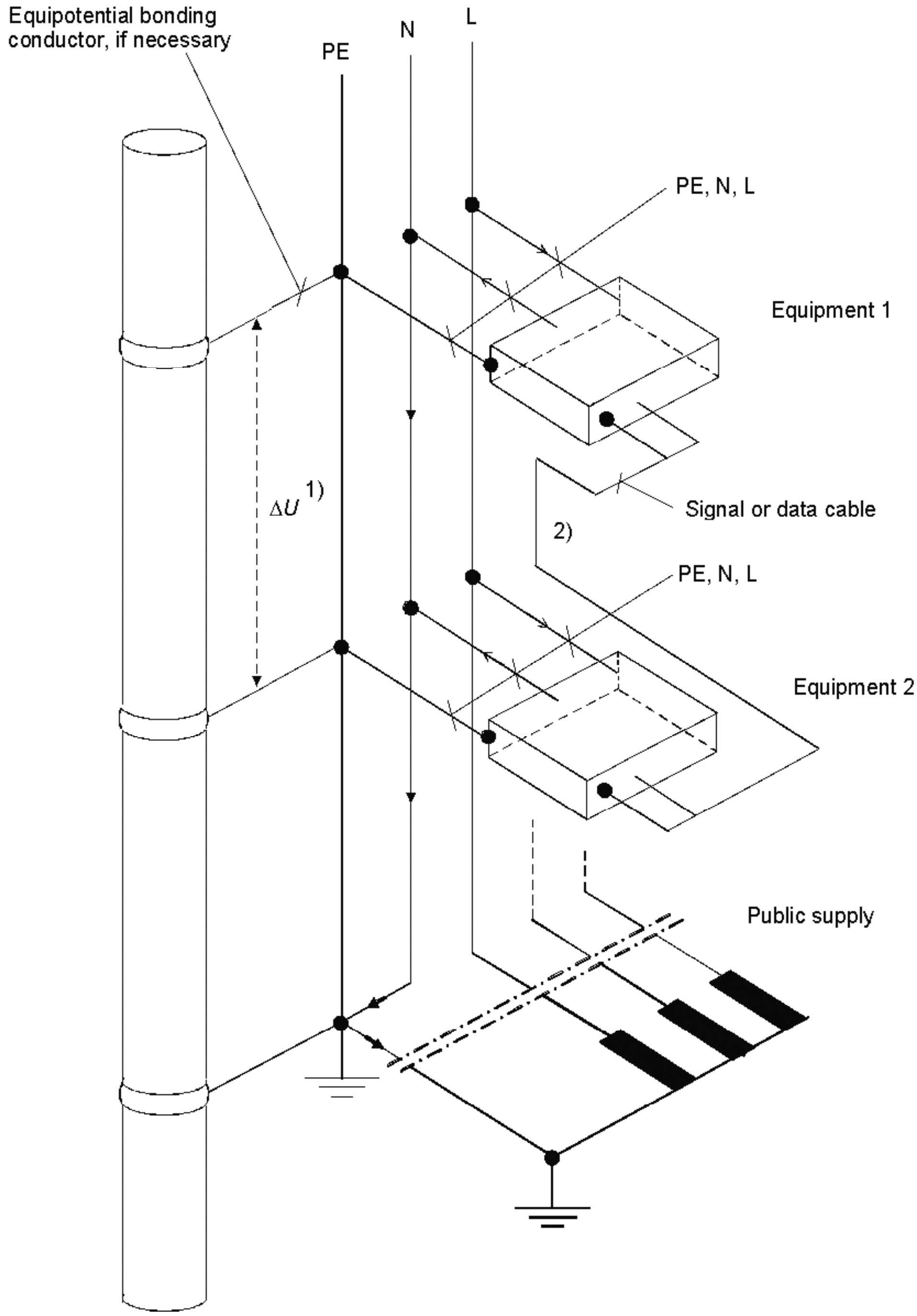
In a three-phase IT system (*see* Fig. 35), the voltage between a healthy line-conductor and an exposed-conductive-part can rise to the level of the line-to-line voltage when there is a single insulation fault between a line conductor and an exposed-conductive-part; this condition should be considered.

NOTE — Electronic equipment directly supplied between line conductor and neutral should be designed to withstand such a voltage between line conductor and exposed-conductive-parts; see corresponding requirement from IS 13252 (Part 1) for information technology equipment.

4.5.4.4.6 *Multiple-source supply*

For multiple-source power supplies, the provisions given in **4.5.4.4.6.1** and **4.5.4.4.6.2** shall be applied.

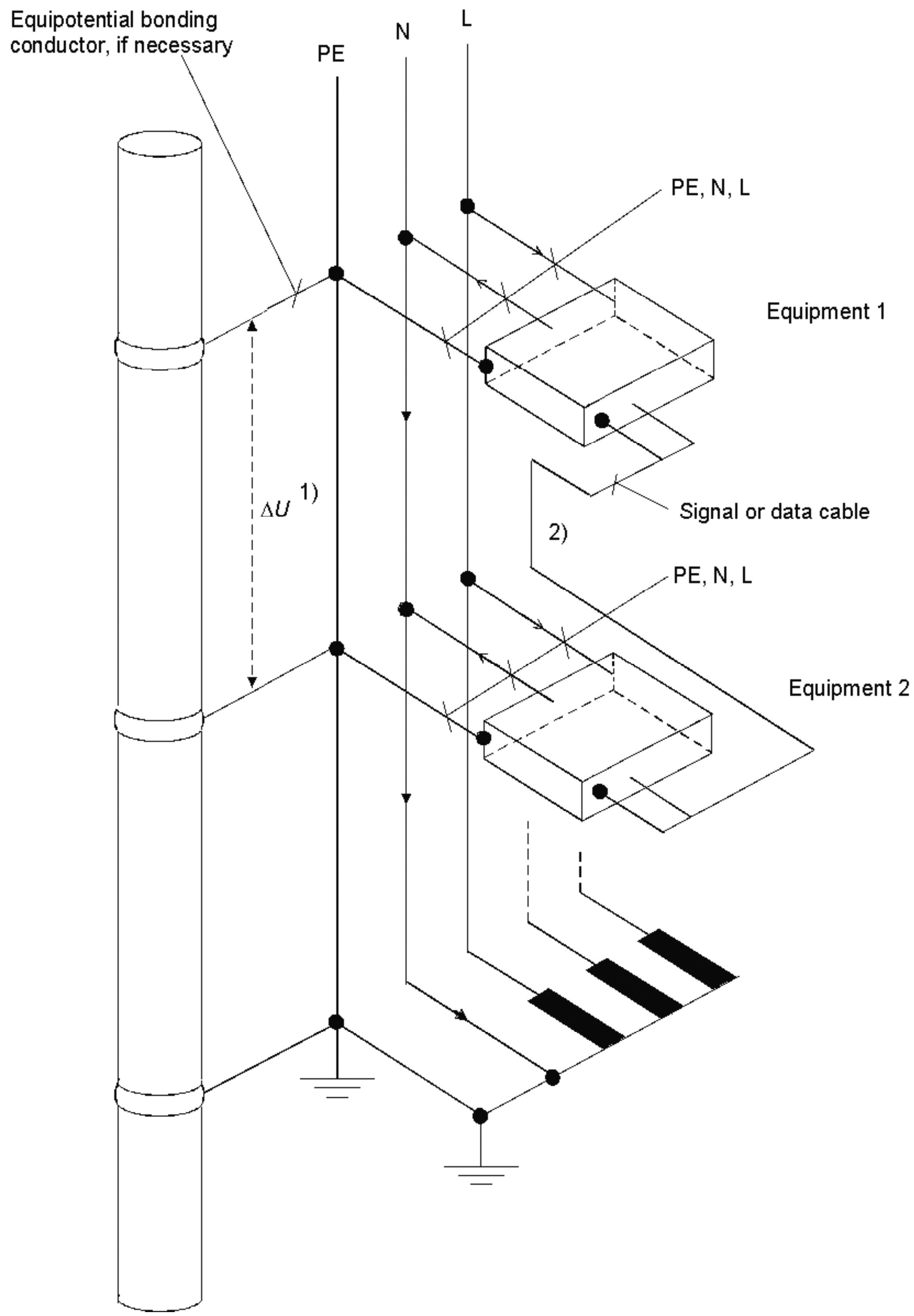
In the case of single conductor cables, which carry a.c. current, a circular electromagnetic field is generated



1) — No voltage drop ΔU along the PE conductor under normal operation conditions.

2) — Loops of limited area formed by signal or data cables.

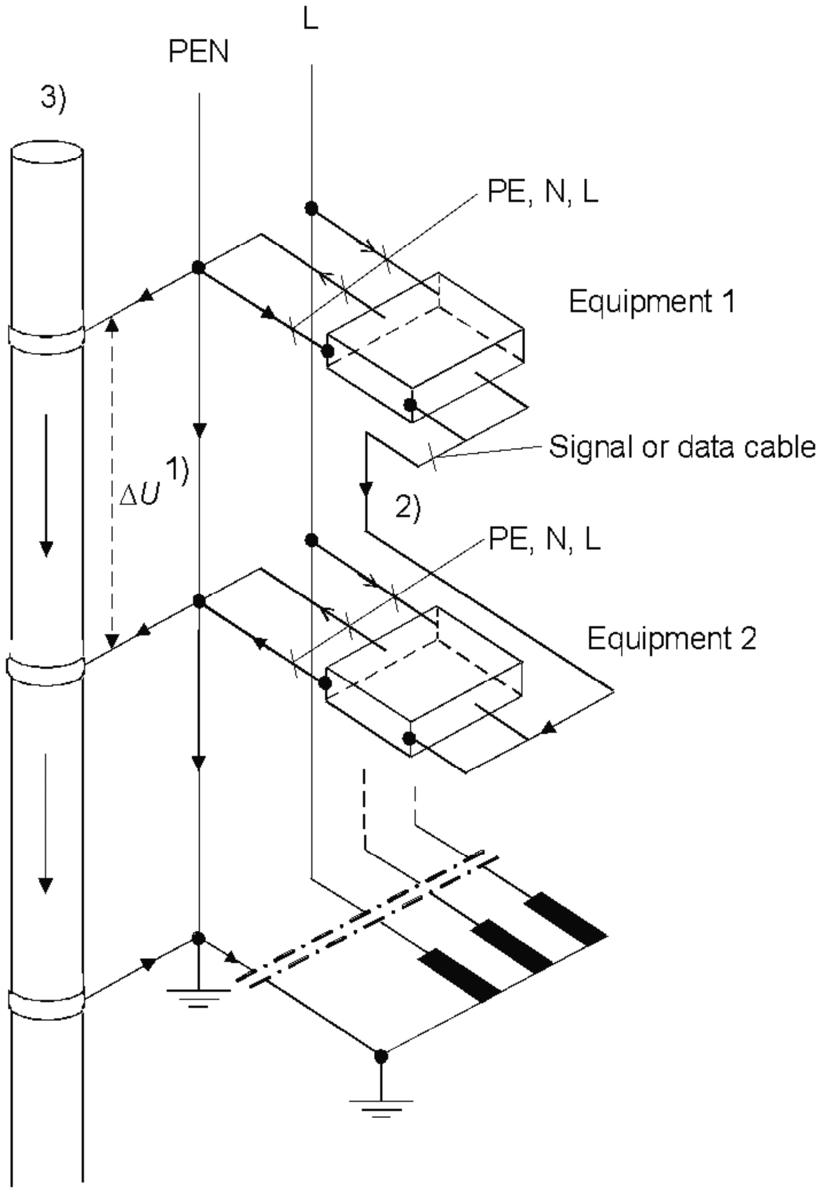
FIG. 31 AVOIDANCE OF NEUTRAL CONDUCTOR CURRENTS IN A BONDED STRUCTURE BY USING THE TN-S SYSTEM FROM THE ORIGIN OF THE PUBLIC SUPPLY UP TO AND INCLUDING THE FINAL CIRCUIT WITHIN A BUILDING



1) — No voltage drop ΔU along the PE conductor under normal operation conditions.

2) — Loops of limited area formed by signal or data cables.

FIG. 32 AVOIDANCE OF NEUTRAL CONDUCTOR CURRENTS IN A BONDED STRUCTURE BY USING A TN-S SYSTEM DOWNSTREAM OF A CONSUMER'S PRIVATE SUPPLY TRANSFORMER



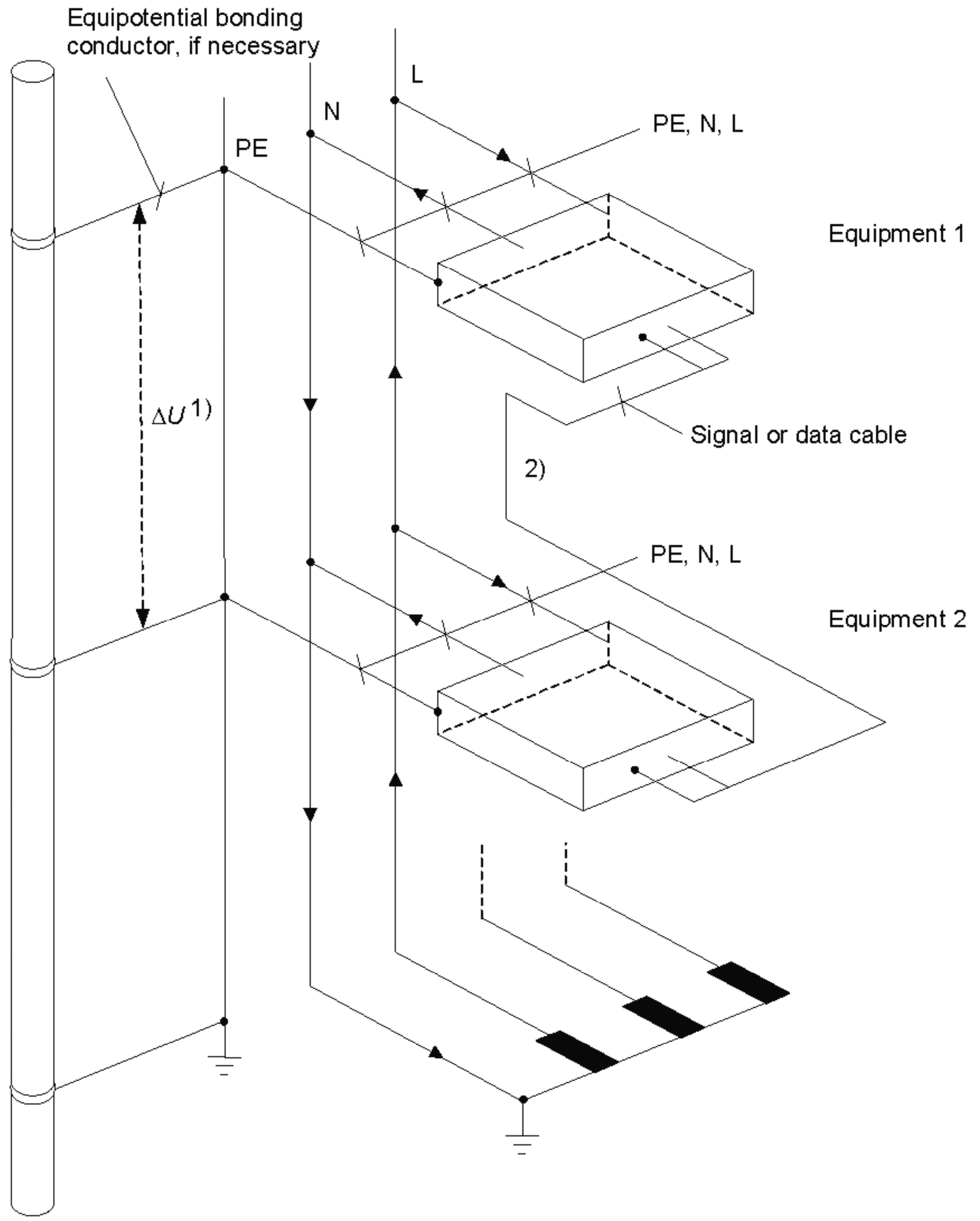
1) — Voltage drop ΔU along PEN in normal operation.

2) — Loop of limited area formed from signal or data cables.

3) — Extraneous-conductive-part.

NOTE — In a TN-C-S system, the current, which in a TN-S system would flow only through the neutral conductor, flows also through the screens or reference conductors of signal cables, exposed-conductive-parts, and extraneous- conductive-parts such as structural metalwork.

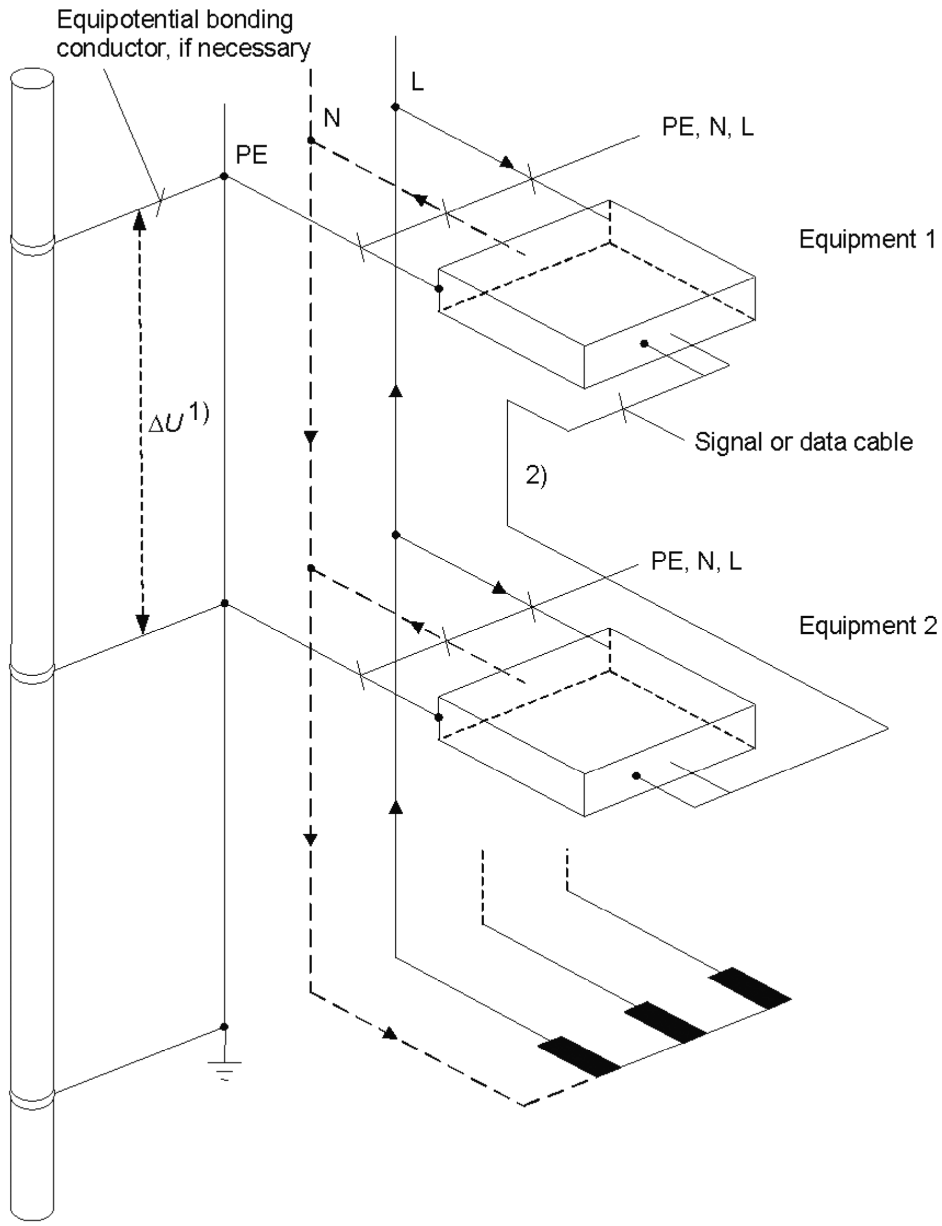
FIG. 33 TN-C-S SYSTEM WITHIN AN EXISTING BUILDING INSTALLATION



1) — Voltage drop ΔU along PEN in normal operation.

2) — Loop of limited area formed from signal or data cables.

FIG. 34 TT SYSTEM WITHIN A BUILDING INSTALLATION



1) — Voltage drop ΔU along PEN in normal operation.

2) — Loop of limited area formed from signal or data cables.

FIG. 35 IT SYSTEM WITHIN A BUILDING INSTALLATION

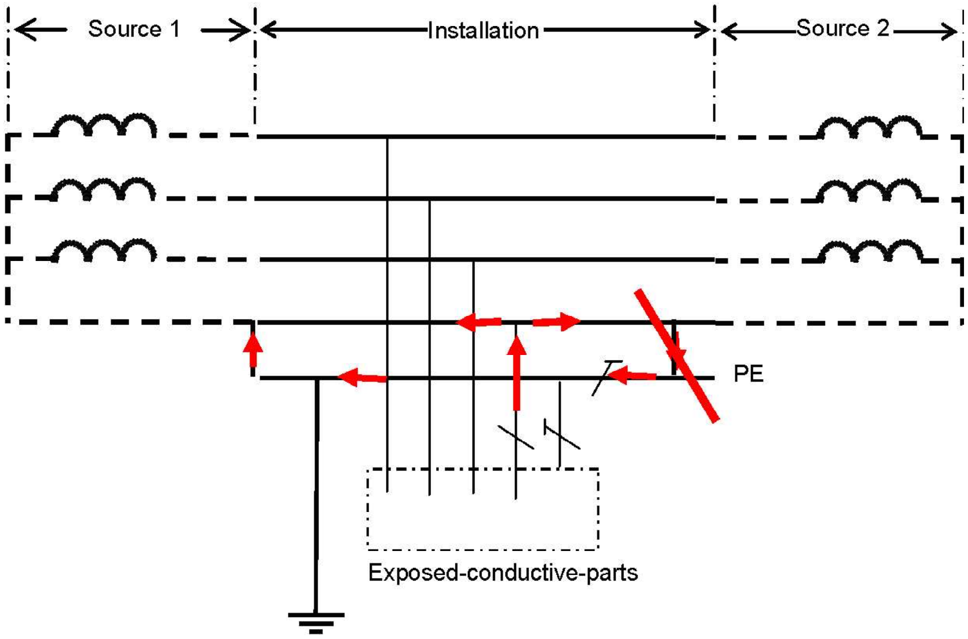


FIG. 36 TN MULTIPLE-SOURCE POWER SUPPLY WITH A NON-SUITABLE MULTIPLE CONNECTION BETWEEN PEN AND EARTH

around the core conductor that may interfere with electronic equipment. Harmonic currents produce similar electromagnetic fields but they attenuate more rapidly than those produced by fundamental currents.

4.5.4.4.6.1 *TN multiple source power supplies*

In the case of TN multiple-source power supplies to an installation, the star points of the different sources shall, for EMC reasons, be interconnected by an insulated conductor that is connected to earth centrally at one and the same point (*see* Fig. 37).

4.5.4.4.6.2 *TT multiple-source power supplies*

In the case of TT multiple-source power supplies to an installation, it is recommended that the star points of the different sources are, for EMC reasons, interconnected and connected to earth centrally at only one point (*see* Fig. 38).

4.5.4.4.7 *Transfer of supply*

In TN systems the transfer from one supply to an alternative supply shall be by means of a switching device, which switches the line conductors and the neutral, if any (*see* Fig. 39, Fig. 40 and Fig. 41).

4.5.4.4.8 *Services entering a building*

Metal pipes (for example, for water, gas or district heating) and incoming power and signal cables should preferably enter the building at the same place. Metal pipes and the metal armouring of cables shall be bonded to the main earthing terminal by means of conductors having low impedance (*see* Fig. 42).

NOTE — Interconnection is only permitted with the consent of the operator of the external service.

For EMC reasons, closed building voids housing parts of the electrical installation should be exclusively reserved for electrical and electronic equipment (such as monitoring, control or protection devices, connecting devices, etc) and access shall be providedfor their maintenance.

4.5.4.4.9 *Separate buildings*

Where different buildings have separate equipotential bonding systems, metal-free fibre optic cables or other non-conducting systems may be used for signal and data transmission, for example, microwave signal transformer for isolation in accordance with IEC 61558-2-1, IEC 61558-2-4, IEC 61588-2-6, IEC 61888-2-15 and IS 13252 (Part 1).

NOTES

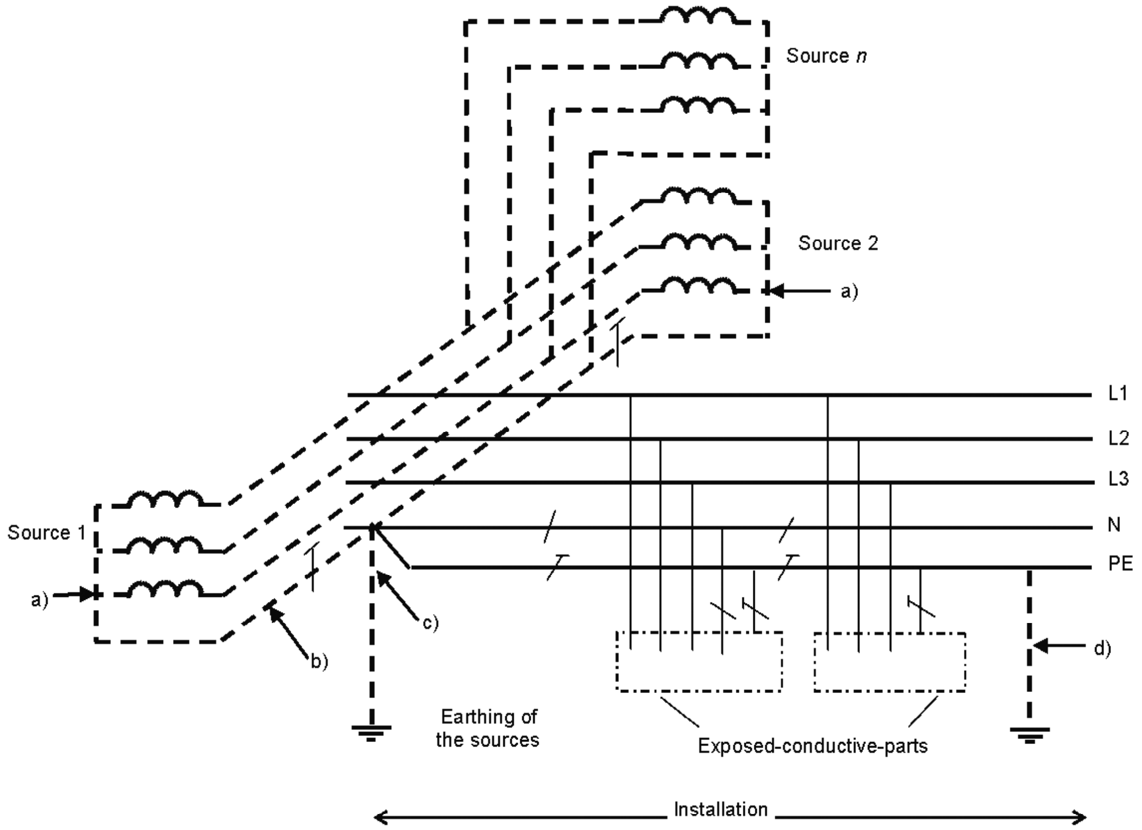
1 The problem of earth differential voltages on large public telecommunication networks is the responsibility of the network operator, who may employ other methods.

2 In case of non-conducting data-transmission systems, the use of a by-pass conductor is not necessary.

4.5.4.4.10 *Inside buildings*

Where there are problems in existing building installations due to electromagnetic influences, the following measures may improve the situation (*see* Fig. 43):

1) use of metal free fibre optic links for signal and data circuits (*see* **4.5.4.4.9**);
2) use of Class II equipment; and



a) — No direct connection from either transformer neutral points or generator star points to earth is permitted.

b) — The conductor interconnecting either the neutral points of transformers, or the star-points of generators, shall be insulated. This conductor functions as a PEN conductor and it may be marked as such; however, it shall not be connected to current-using-equipment and a warning notice to that effect shall be attached to it, or placed adjacent to it.

c) — Only one connection between the interconnected neutral points of the sources and the PE shall be provided. This connection shall be located inside the main switchgear assembly.

d) — Additional earthing of the PE in the installation must be provided.

FIG. 37 TN MULTIPLE SOURCE POWER SUPPLIES TO AN INSTALLATION WITH CONNECTION TO EARTH OF THE STAR POINTS AT ONE AND THE SAME POINTS

3) use of double winding transformers in compliance with IEC 61558-2-1 or IEC 61558-2-4 or IS/IEC 61558-2-6 or IEC 61558-2-15. The secondary circuit should preferably be connected as a TN-S system but an IT-system may be used where required for specific applications.

4.5.4.4.11 *Protective devices*

Protective devices with appropriate functionality for avoiding unwanted tripping due to high levels of transient currents should be selected, for example, time delays and filters.

4.5.4.4.12 *Signal cables*

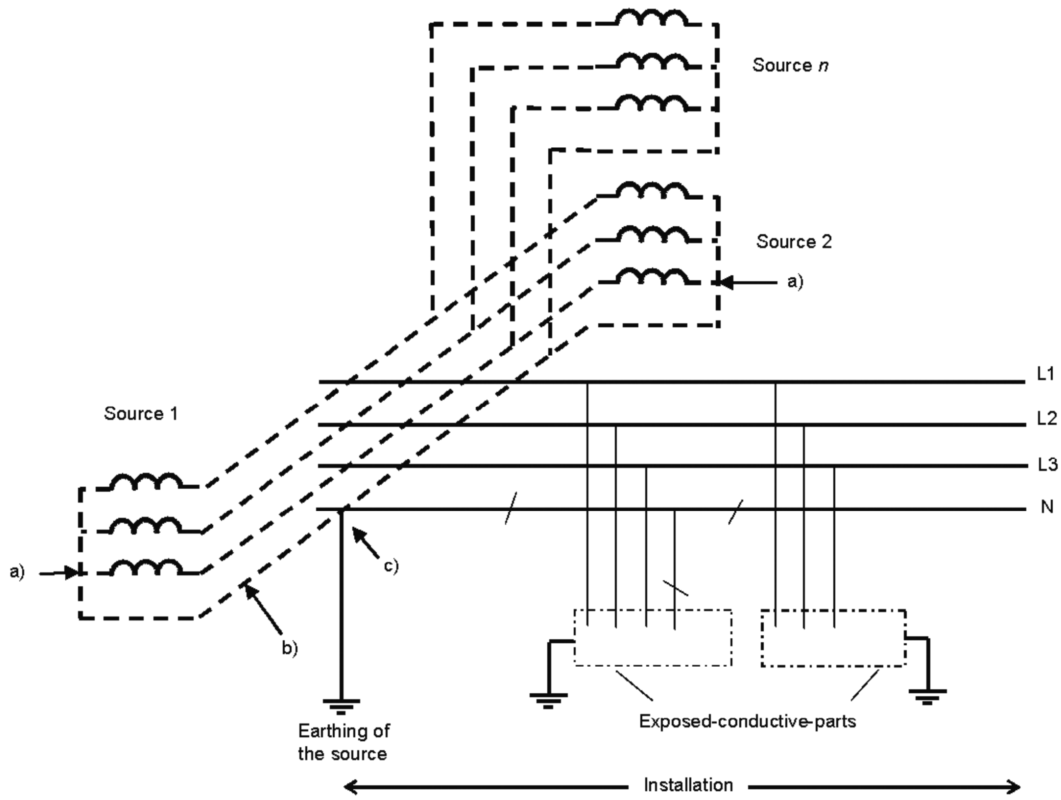
Shielded cables and/or twisted pair cables should be used for signal cables.

4.5.4.5 *Earthing and equipotential bonding*

4.5.4.5.1 *Interconnection of earth electrodes*

For several buildings, the concept of dedicated and independent earth electrodes connected to an equipotential conductor network may not be adequate where electronic equipment is used for communication and data exchange between the different buildings for the following reasons:

a) a coupling exists between these different earth electrodes and leads to an uncontrolled increase of voltage to equipment;
b) interconnected equipment may have different earth references; and
c) a risk of electric shock exists, specifically in case of overvoltages of atmospheric origin.



a) — No direct connection from either the transformer star points or the generator star points to earth is permitted.

b) — The conductor interconnecting either the star points of transformers, or generator star points, shall be insulated. However, it shall not be connected to current-using-equipment and a warning notice to that effect shall be attached to it, or placed adjacent to it.

c) — Only one connection between the interconnected star points of the sources and the PE shall be provided. This connection shall be located inside the main switchgear assembly.

FIG. 38 TT MULTIPLE-SOURCE POWER SUPPLIES TO AN INSTALLATION WITH CONNECTION TO EARTH OF THE STAR POINTS AT ONE AND THE SAME POINT

Therefore, all protective and functional earthing conductors should be connected to one single main earthing terminal.

Moreover, all earth electrodes associated with a building, for example, protective, functional and lightning protection, shall be interconnected (*see* Fig. 44).

In the case of several buildings, where interconnection of the earth electrodes is not possible or practical, it is recommended that galvanic separation of communication networks is applied, for instance by the use of fibre optic links (*see also* **4.5.4.4.10**).

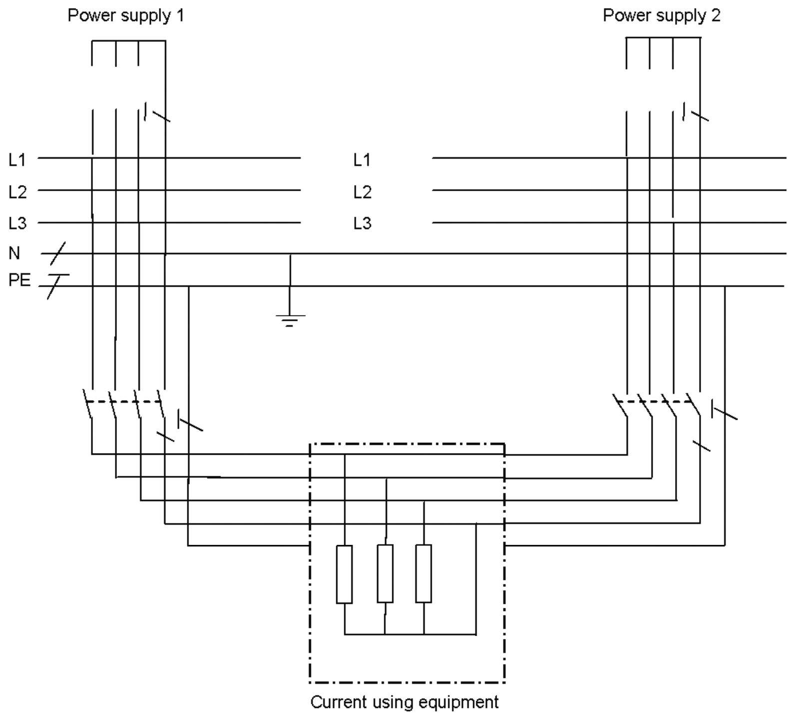
Protective and functional bonding conductors shall be connected individually to the main earthing terminal in such a way that if one conductor becomes disconnected the connections of all the other conductors remain secured.

4.5.4.5.2 *Interconnection of incoming networks and earthing arrangements*

Exposed conductive parts of information technology and electronic equipment within a building are interconnected via protective conductors.

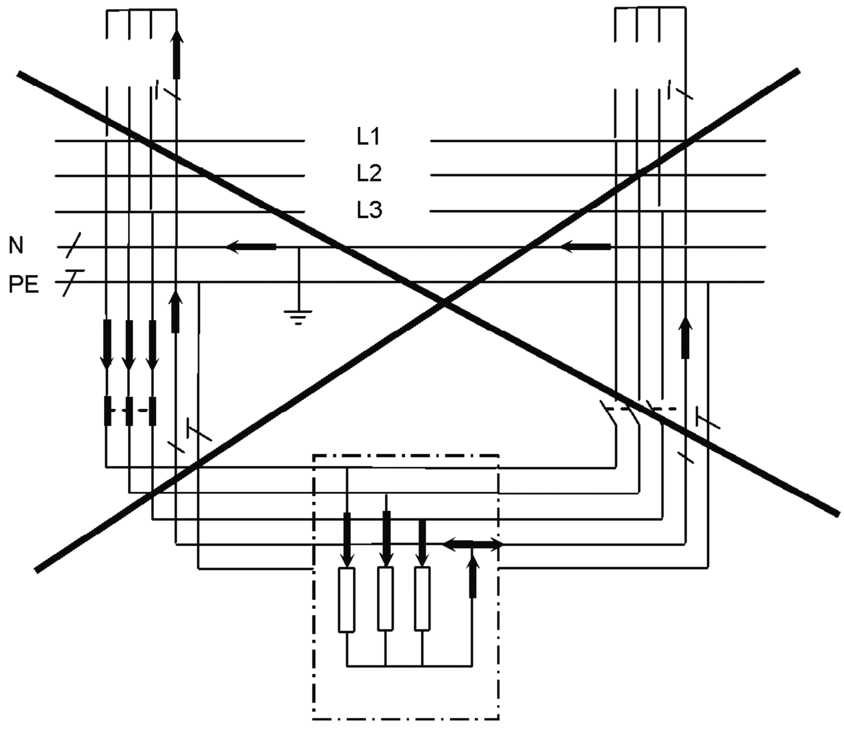
For dwellings where normally a limited amount of electronic equipment is in use, a protective conductor network in the form of a star network may be acceptable (*see* Fig. 45).

For commercial and industrial buildings and similar buildings containing multiple electronic applications, a common equipotential bonding system is useful in order to comply with the EMC requirements of different types of equipment (*see* Fig. 47).



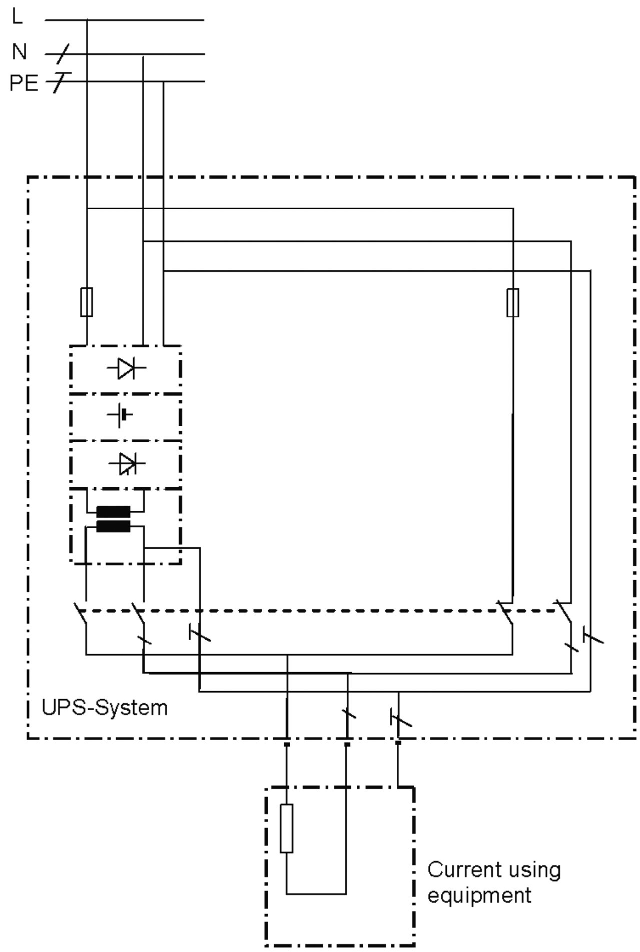
NOTE — This method prevents electromagnetic fields due to stray currents in the main supply system of an installation. The sum of the currents within one cable must be zero. It ensures that the neutral current flows only in the neutral conductor of the circuit, which is switched on. The 3rd harmonic (150 Hz) current of the line conductors will be added with the same phase angle to the neutral conductor current.

FIG. 39 THREE-PHASE ALTERNATIVE POWER SUPPLY WITH A 4-POLE SWITCH



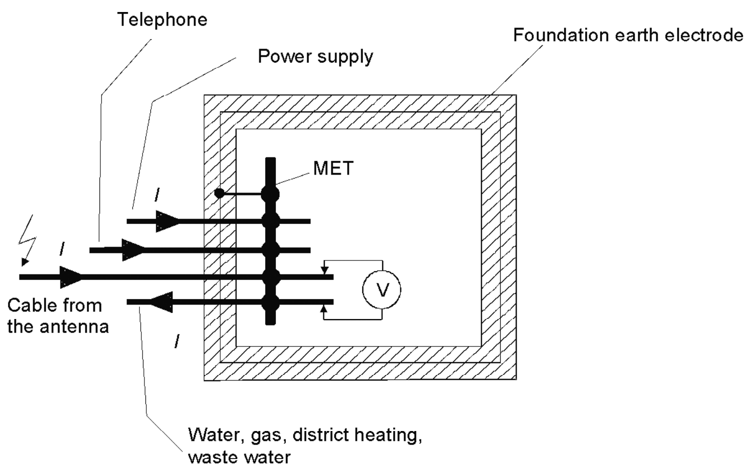
NOTE — A three-phase alternative power supply with an unsuitable 3-pole switch will cause unwanted circulating currents, that will generate electromagnetic fields.

FIG. 40 NEUTRAL CURRENT FLOW IN A THREE-PHASE ALTERNATIVE POWER SUPPLY WITH AN UNSUITABLE 3-POLE SWITCH



NOTE — The earth connection to the secondary circuit of a UPS is not mandatory. If the connection is omitted, the supply inthe UPS-mode will be in the form of an IT system and, in by-pass mode, it will be the same as the low-voltage supply system.

FIG. 41 SINGLE-PHASE ALTERNATIVE POWER SUPPLY WITH 2-POLE SWITCH

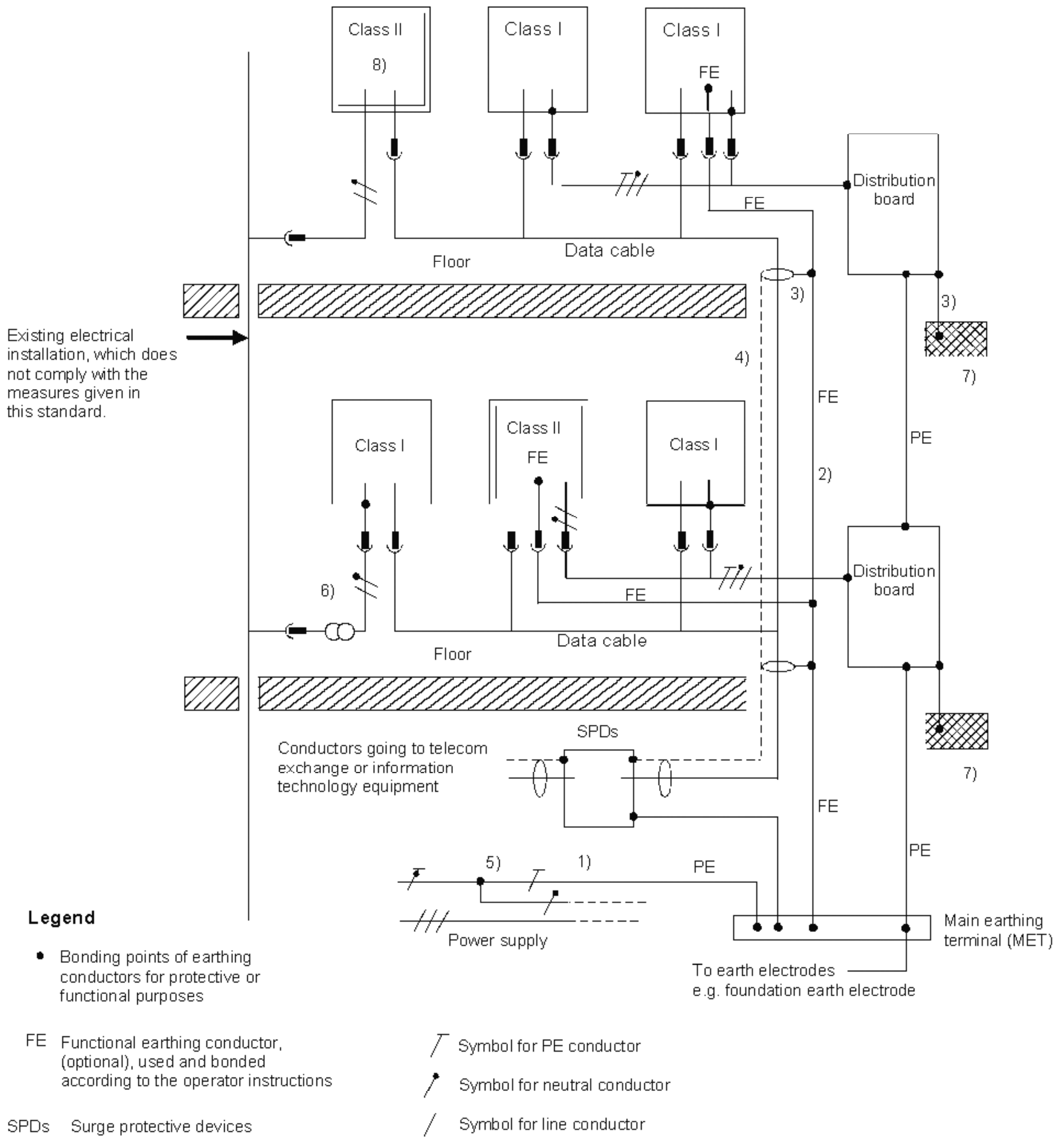


MET — Main earthing terminal

I — Induction current

NOTE — A common entry point is preferred, *U*E” 0 V.

FIG. 42 ARMOURED CABLES AND METAL PIPES ENTERING THE BUILDINGS (EXAMPLES)



Reference	*Description of the Illustrated Measures*	*Sub-Clause/ Standard*
1)	Cables and metal pipes enter the building at the same place	**4.5.4.4.8**
2)	Common route with adequate separations and avoidance of loops	**4.5.4.4.2**
3)	Bonding leads as short as possible, and use of earthed conductor parallel to a cable	IEC 61000-2-5 **4.5.4.4.2**
4)	Signal cables screened and/or conductors twisted pairs	**4.5.4.4.12**
5)	Avoidance of TN-C beyond the incoming supply point	**4.5.4.4.3**
6)	Use of transformers with separate windings	**4.5.4.4.10**
7)	Local horizontal bonding system	**4.5.4.5.4**
8)	Use of class II equipment	**4.5.4.4.10**

FIG. 43 ILLUSTRATION OF MEASURES IN AN EXISTING BUILDING

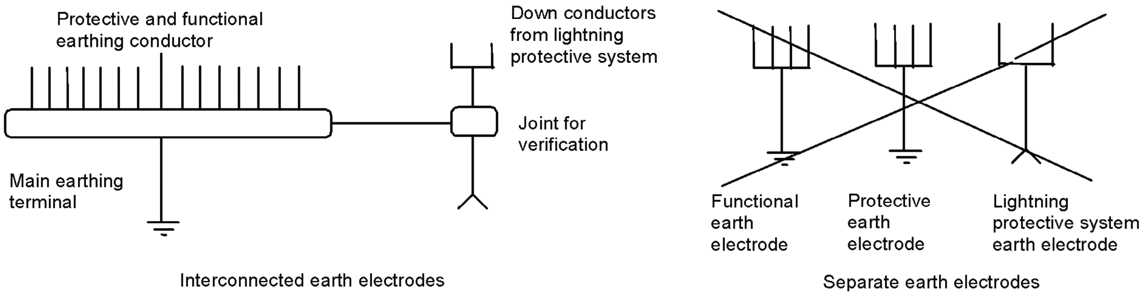


FIG. 44 INTERCONNECTED EARTH ELECTRODES

4.5.4.5.3 *Different structures for the network of equipotential conductors and earthing conductors*

The four basic structures described in the following sub-clauses may be used, depending on the importance and vulnerability of equipment.

4.5.4.5.3.1 *Protective conductors connected to a bonding-ring conductor*

An equipotential bonding network in the form of a bonding ring conductor, BRC, is shown in Fig. 48 on the top-floor of the structure. The BRC should preferably be made of copper, bare or insulated, and installed in such a manner that it remains accessible everywhere, for example, by using a cable-tray, metallic conduit [*see* IS 14930 (Part 1 and Part 2)], surface mounted method of installation or cable trunking. All protective and functional earthing conductors may be connected to the BRC.

4.5.4.5.3.2 *Protective conductors in a star network*

This type of network is applicable to small installations associated with dwellings, small commercial buildings, etc, and from a general point of view to equipment, that is not interconnected by signal cables (*see* Fig. 45).

4.5.4.5.3.3 *Multiple meshed bonding star network*

This type of network is applicable to small installations with different small groups of interconnected communicating equipment. It enables the local dispersion of currents caused by electromagnetic interference (*see* Fig. 46).

4.5.4.5.3.4 *Common meshed bonding star network*

This type of network is applicable to installations with high density of communicating equipment corresponding to critical applications (*see* Fig. 47).

A meshed equipotential bonding network is enhanced by the existing metallic structures of the building. It is supplemented by conductors forming the square mesh.

The mesh-size depends on the selected level of protection against lightning, on the immunity level of equipment part of the installation and on frequencies used for data transmission.

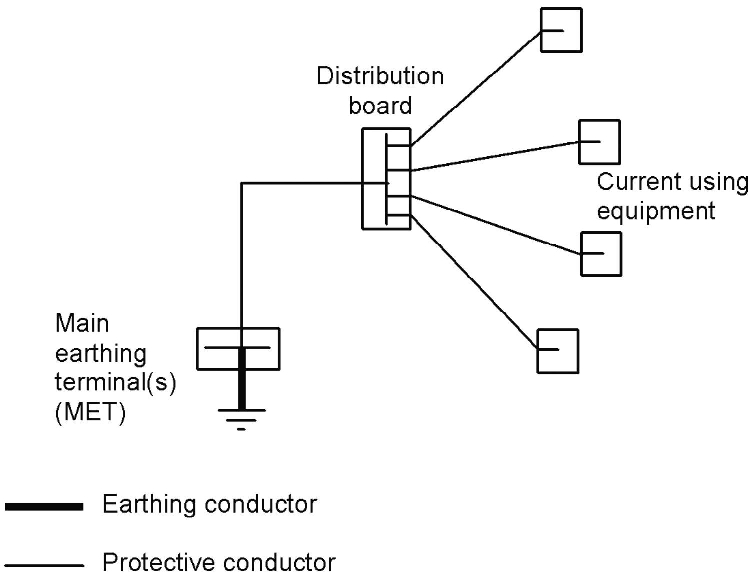


FIG. 45 EXAMPLES OF PROTECTIVE CONDUCTORS IN STAR NETWORK

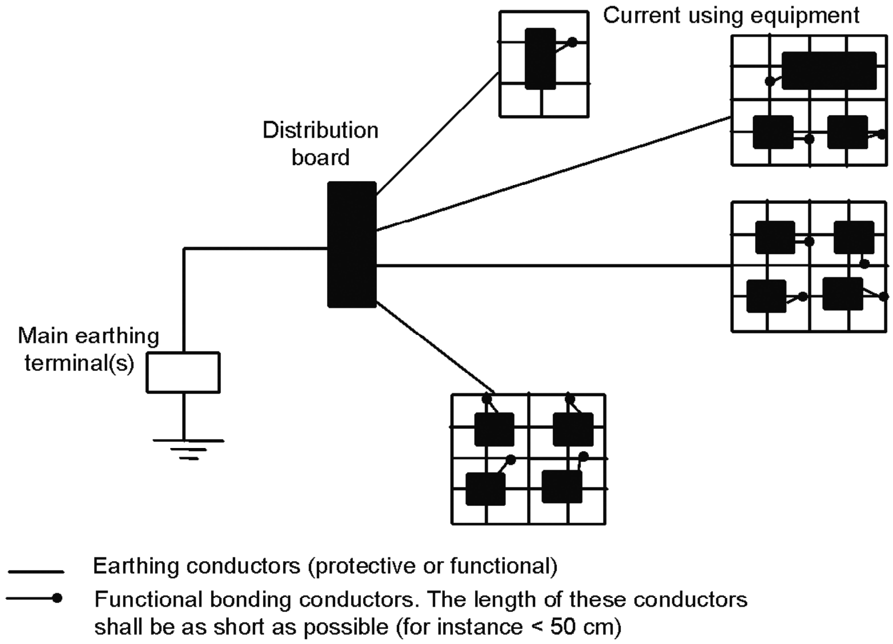
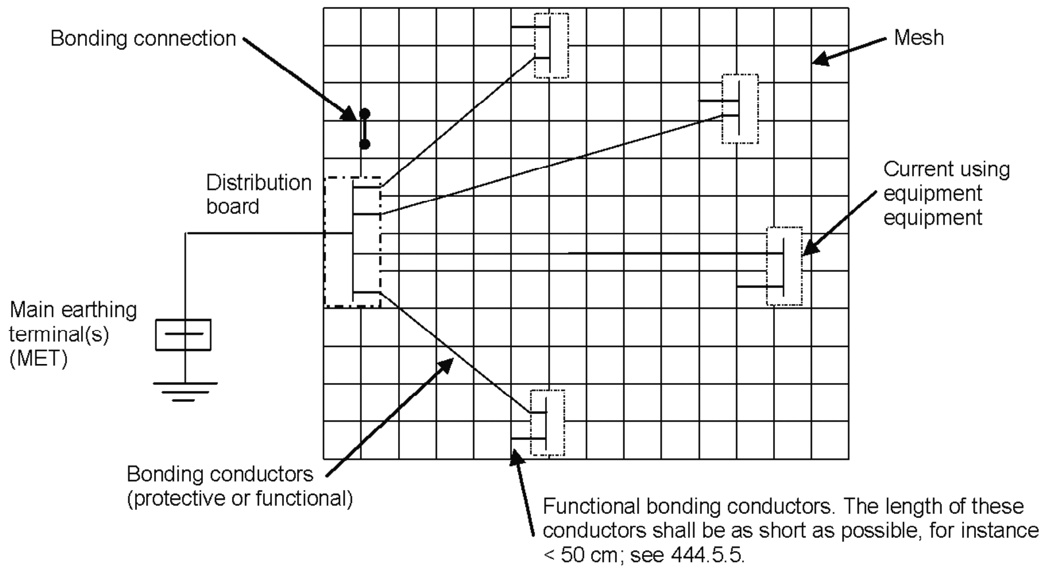


FIG. 46 EXAMPLE OF MULTIPLE MESHED BONDING STAR NETWORK



The area covered by a mesh shall have overall dimensions; the mesh-size refers to the dimensions of square spaces enclosed by the conductors forming the mesh.

FIG. 47 EXAMPLE OF A COMMON MESHED BONDING STAR NETWORK

Mesh-size shall be adapted to the dimensions of the installation to be protected, but shall not exceed 2 m × 2 m in areas where equipment sensitive to electromagnetic interferences is installed.

It is suitable for protection of private automatic branch exchange equipment (PABX) and centralized data processing systems.

In some cases, parts of this network may be meshed more closely in order to meet specific requirements.

4.5.4.5.4 *Equipotential bonding networks in buildings with several floors*

For buildings with several floors, it is recommended that, on each floor, an equipotential bonding system be installed (*see* Fig. 48) for examples of bonding networks in common use; each floor is a type of

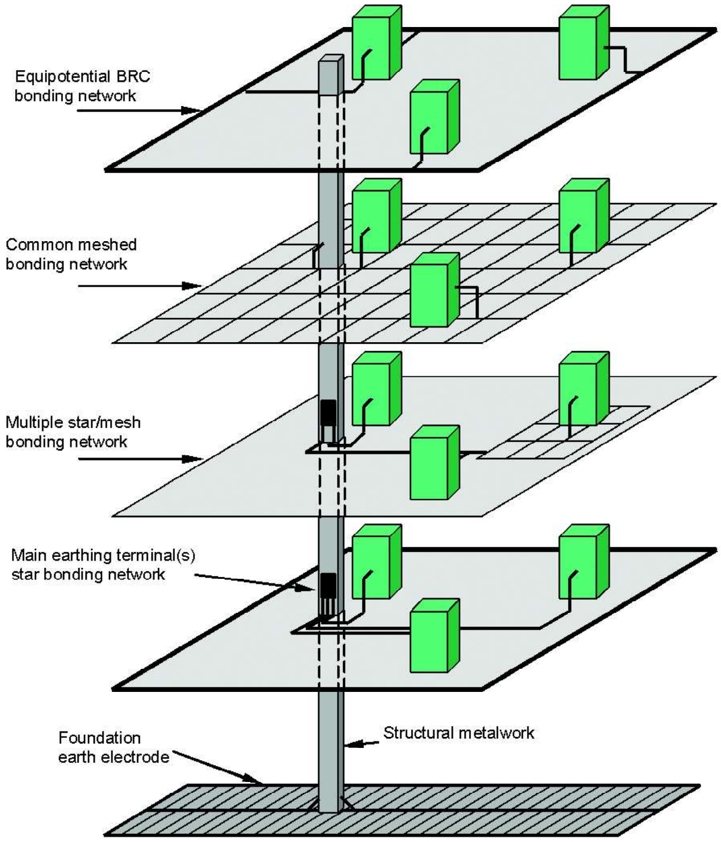


FIG. 48 EXAMPLE OF EQUIPOTENTIAL BONDING NETWORKS IN STRUCTURES WITHOUT LIGHTNING PROTECTION SYSTEMS

network. The bonding systems of the different floors should be interconnected, at least twice, by conductors.

4.5.4.5.5 *Functional earthing conductor*

Some electronic equipment requires a reference voltage at about earth potential in order to function correctly; this reference voltage is provided by the functional earthing conductor.

Conductors for functional earthing may be metallic strips, flat braids and cables with circular cross-section.

For equipment operating at high frequencies, metallic strips or flat braids are preferred and the connections shall be kept as short as possible.

No colour is specified for functional earthing conductors. However, the colours green-and-yellow specified for earthing conductors shall not be used. It is recommended that the same colour is used throughout the whole installation to mark functional earthing conductors at each end.

For equipment operating at low frequencies, cross sectional areas as indicated in **5.4.4.1** are considered satisfactory, independent of the conductor shape [*see* **4.5.4.4.2** (b) and (k)].

4.5.4.5.6 *Commercial or industrial buildings containing significant amounts of information technology equipment*

The following additional specifications are intended to reduce the influences of electromagnetic disturbances on the information technology equipment operation.

In severe electromagnetic environments, it is recommended that the common meshed bonding star network described in **4.5.4.5.3.3** be adopted.

4.5.4.5.6.1 Equipotential bonding designed as a bonding ring network shall have the following minimum dimensions:

a) flat copper cross-section: 30 mm × 2 mm.
b) round copper diameter: 8 mm.
c) as per IS 3043

Bare conductors shall be protected against corrosion at their supports and on their passage through walls.

4.5.4.5.6.2 *Parts to be connected to the equipotential bonding network*

The following parts shall also be connected to the equipotential bonding network:

a) conductive screens, conductive sheaths or armouring of data transmission cables or of information technology equipment;
b) earthing conductors of antenna systems;
c) earthing conductors of the earthed pole of d.c. supply for information technology equipment; and
d) functional earthing conductors.

4.5.4.5.7 *Earthing arrangements and equipotential bonding of information technology installations for functional purposes*

4.5.4.5.7.1 *Earthing busbar*

Where an earthing busbar is required for functional purposes, the main earthing terminal (MET) of the building may be extended by using an earthing busbar. This enables information technology installations to be connected to the main earthing terminal by the shortest practical route from any point in the building. Where the earthing busbar is erected to support the equipotential bonding network of a significant amount of information technology equipment in a building, it may be installed as a bonding ring network; *see* Fig. 48.

NOTES

1 The earthing busbar may be bare or insulated.

2 The earthing busbar should preferably be installed so that it is accessible throughout its length, e.g. on the surface of trunking. To prevent corrosion, it may be necessary to protect bare conductors at supports and where they pass throughout walls.

4.5.4.5.7.2 *Cross-sectional area of the earthing busbar*

The effectiveness of the earthing busbar depends on the routing and the impedance of the conductor employed. For installations connected to a supply having a capacity of 200 A per phase or more, the cross-sectional area of the earthing busbar shall be not less than 50 mm^2 copper and shall be dimensioned in accordance with **4.5.4.4.2** (k).

NOTE — This statement is valid for frequencies up to 10 MHz.

Where the earthing busbar is used as part of a d.c. return current path, its cross-sectional area shall be dimensioned according to the expected d.c. return currents. The maximum DC voltage drop along each earthing busbar, dedicated as d.c. distribution return conductor, shall be designed to be less than 1 V.

4.5.4.6.1 *General*

Information technology cables and power supply cables, which share the same cable management system or the same route, shall be installed according to the requirements of the following sub-clauses.

Verification of electrical safety, in accordance with **6.2** and/or **5.1**, and electrical separation are required (*see* **4.2.13** and/or **4.5.4.7.2**). Electrical safety and electromagnetic compatibility require different clearances in some cases. Electrical safety always has the higher priority.

Exposed conductive parts of wiring systems, for example, sheaths, fittings and barriers, shall be protected by requirements for fault protection (*see* **4.2.13**).

4.5.4.6.2 *Design guidelines*

The minimum separation between power cables and information technology cables to avoid disturbance is related to many factors such as:

a) the immunity level of equipment connected to the information technology cabling system to different electromagnetic disturbances (transients, lightning pulses, bursts, ring wave, continuous waves, etc).
b) the connection of equipment to earthing systems.
c) the local electromagnetic environment (simultaneous appearance of disturbances, for example harmonics plus bursts plus continuous wave).
d) the electromagnetic frequency spectrum.
e) the distances that cables are installed in parallel routes (coupling zone).
f) the types of cables.
g) the coupling attenuation of the cables.
h) the quality of the attachment between the connectors and the cable.
j) the type and construction of the cable management system.

For the purpose of this standard, it is assumed that the electromagnetic environment has levels of disturbance less than the test levels for conducted and radiated disturbances contained in IS 14700(Part 4/Sec 1), IEC 61000-6-2, IS 14700 (Part 4/Sec 3) and IS 14700 (Part 4/Sec 4).

For parallel power and information technology cabling, the following applies (*see* Fig. 49 and Fig. 50).

If the parallel cabling length is equal to or less than 35 m, no separation is required.

If the parallel cabling length of unscreened cable is greater than 35 m, the separation distances apply to the full length excluding the final 15 m attached to the outlet.

NOTE — The separation may be achieved, for example, by a separation distance in air of 30 mm or a metallic divider installed between the cables, *see also* Fig. 51.

If the parallel cabling length of screened cable is greater than 35 m, no separation distances are applicable.

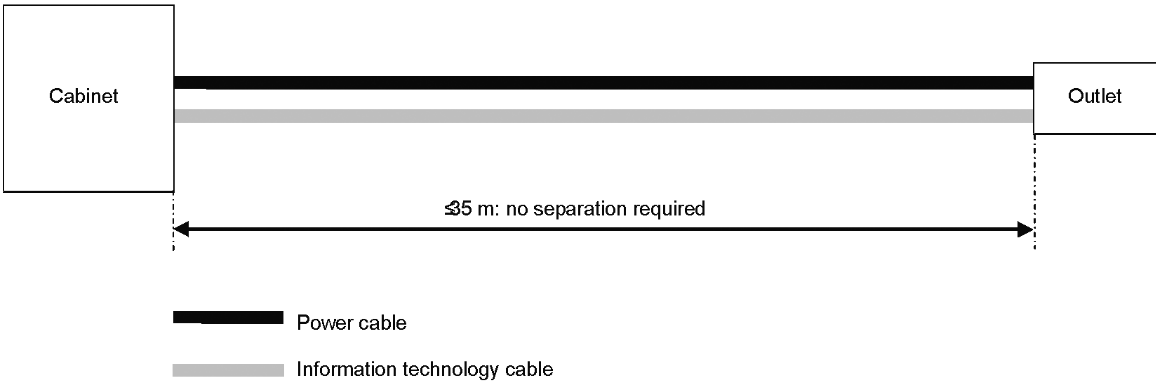


FIG. 49 SEPARATION BETWEEN POWER AND INFORMATION TECHNOLOGY CABLES FOR CABLE ROUTE LENGTHS ≤ 35 m

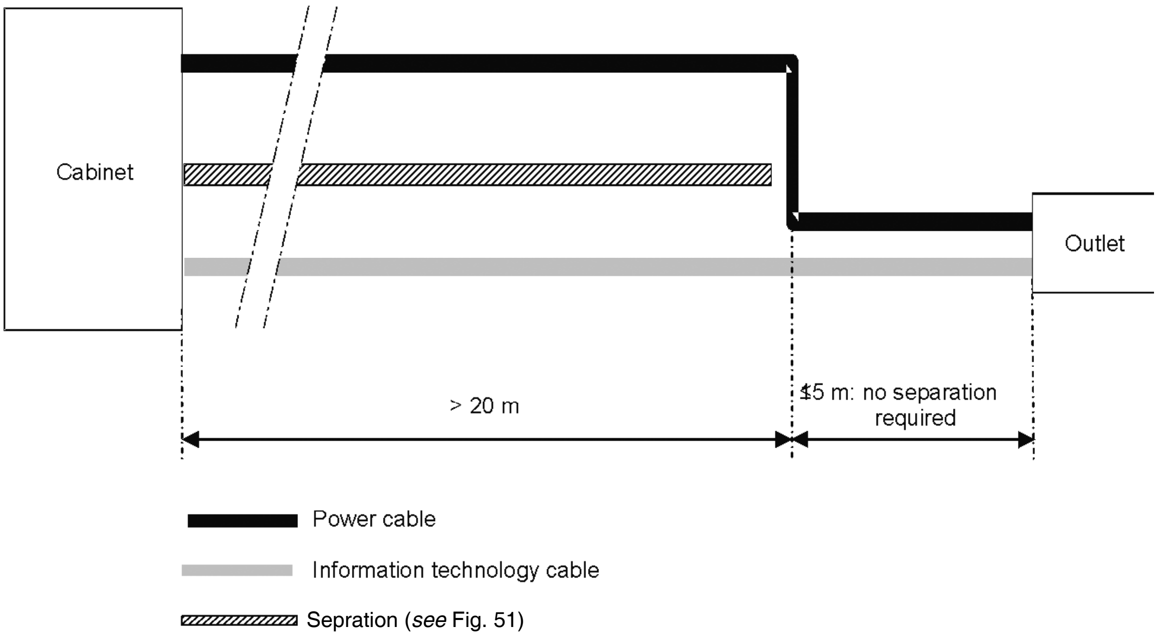


FIG. 50 SEPARATION BETWEEN POWER AND INFORMATION TECHNOLOGY CABLES FOR CABLE ROUTE LENGTHS > 35 m

4.5.4.6.3 *Installation guidelines*

The minimum distance between information technology cables and fluorescent, neon, and mercury vapour (or other high-intensity discharge) lamps shall be 130 mm. Electrical wiring assemblies and data wiring assemblies should preferably be in separate cabinets. Data wiring racks and electrical equipment should always be separated.

Cables should, wherever practical, cross at right angles. Cables for different purposes (for example, mains power and information technology cables) should not be in the same bundle. Different bundles should be separated electromagnetically from each other (*see* Fig. 51).

4.5.4.7 *Cable management systems*

4.5.4.7.1 *General*

Cable management systems are available in metallic and non-metallic forms. Metallic systems offer varying degrees of enhanced protection to EMI provided that they are installed in accordance with **4.5.4.7.3**.

4.5.4.7.2 *Design guidelines*

The choice of material and the shape of the cable management system depend on the following considerations:

a) the strength of the electromagnetic fields along the pathway (proximity of electromagnetic conducted and radiated disturbing sources);

b) the authorised level of conducted and radiated emissions;
c) the type of cabling (screened, twisted, optical fibre);
d) the immunity of the equipment connected to the information technology cabling system;
e) the other environment constraints (chemical, mechanical, climatic, fire, etc);
f) any future information technology cabling system extension.

Non-metallic wiring systems are suitable in the following cases:

– electromagnetic environment with permanently low levels of disturbance;
– the cabling system has a low emission level;
– optical fibre cabling.

For metallic components of cable support systems, the shape (plane, U-shape, tube, etc), rather than the cross-section will determine the characteristic impedance of the cable management system. Enclosed shapes are best as they reduce common mode coupling.

Usable space within the cable-tray should allow for an agreed quantity of additional cables to be installed. The cable-bundle height shall be lower than the side-walls of the cable-tray, as shown in Fig. 52. The use of overlapping lids improves the cable-tray's electromagnetic compatibility performance.

For a U-shape cable-tray, the magnetic field decreases near the two corners. For this reason, deep side-walls are preferred (*see* Fig. 52).

NOTE — The depth of the section should be at least twice the diameter of the largest cable being considered.

4.5.4.7.3 *Installation guidelines*

4.5.4.7.3.1 *Metallic or composite cable management systems specially designed for electromagnetic compatibility purposes*

Metallic or composite cable management systems specially designed for electromagnetic compatibility purposes shall always be connected to the local equipotential bonding system at both ends. For long distances, that is, greater than 50 m, additional connections to the equipotential bonding system are recommended. All connections shall be as short as possible. Where cable management systems are constructed from several elements, care should be taken

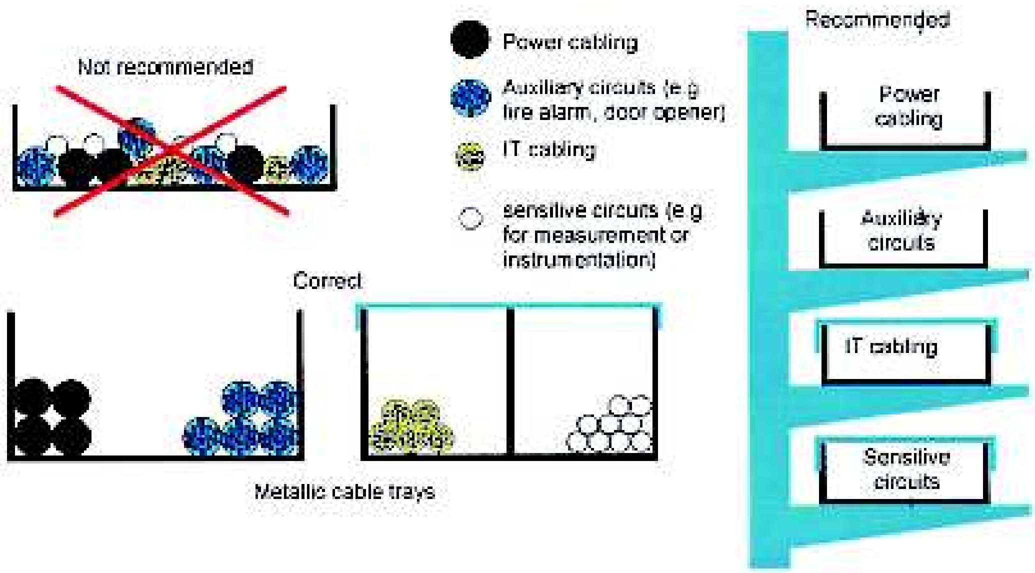


FIG. 51 SEPARATION OF CABLES IN WIRING SYSTEMS

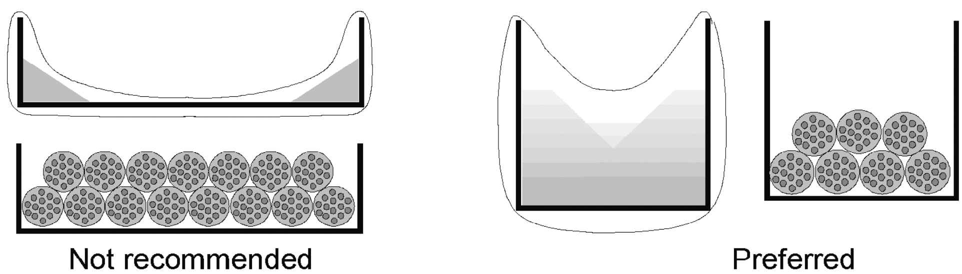


FIG. 52 CABLE ARRANGEMENTS IN METAL CABLE-TRAYS

to ensure continuity by effective bonding between adjacent elements. Preferably, the elements should be welded together over their full perimeter. Riveted, bolted or screwed joints are allowed, provided that the surfaces in contact are good conductors, that is, they have no paint or insulating cover, that they are safeguarded against corrosion and that a good electrical contact between adjacent elements is ensured.

The shape of the metallic section should be maintained over its full length. All interconnections shall have low impedance. A short single-lead connection between two parts of a cable management system will result in a high local impedance and, therefore, degradation of its electromagnetic compatibility performance (*see* Fig. 53).

From frequencies of a few MHz upwards, a 10 cm long mesh strap between two parts of a cable management system will degrade the shielding effect by more than a factor of 10.

Whenever adjustments or extensions are carried out, it is vital that work is closely supervised to ensure that it complies with the electromagnetic compatibility recommendations for example, not replacing a metallic conduit by a plastic one.

Metallic construction elements of buildings can serve electromagnetic compatibility objectives very well. Steel beams of L-, H-, U-, or T-shape often form a continuous earthed structure, that contains large cross-sections and large surfaces with many intermediate connections to earth. Cables are preferably laid against such beams. Inside corners are preferred to outside surfaces (*see* Fig. 54).

Covers for metallic cable trays shall meet the same requirements as the cable trays. A cover with many contacts over the full length is preferred. If that is not possible, the covers should be connected to the cable tray at least at both ends by short connections less than 10 cm, for example, braided or mesh straps.

When a metallic or composite cable management system, specially designed for electromagnetic compatibility purposes, is parted in order to cross a wall, for example, at fire barriers, the two metallic sections shall be bonded with low impedance connections such as braided or mesh straps.

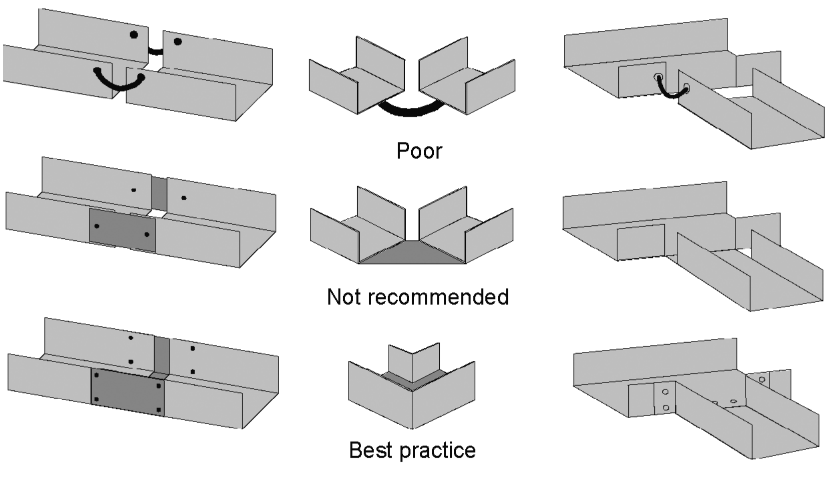


FIG. 53 CONTINUITY OF METALLIC SYSTEM COMPONENTS

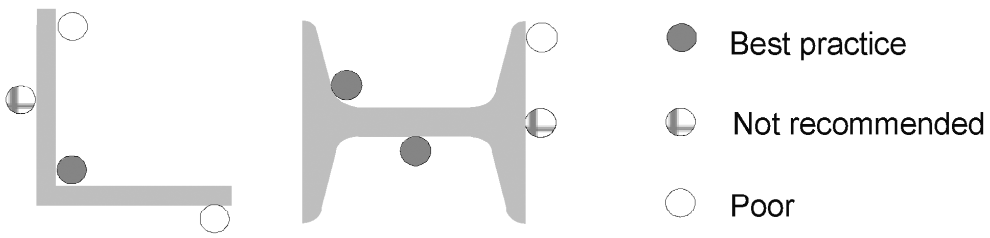


FIG. 54 LOCATION OF CABLES INSIDE METALLIC CONSTRUCTION ELEMENTS

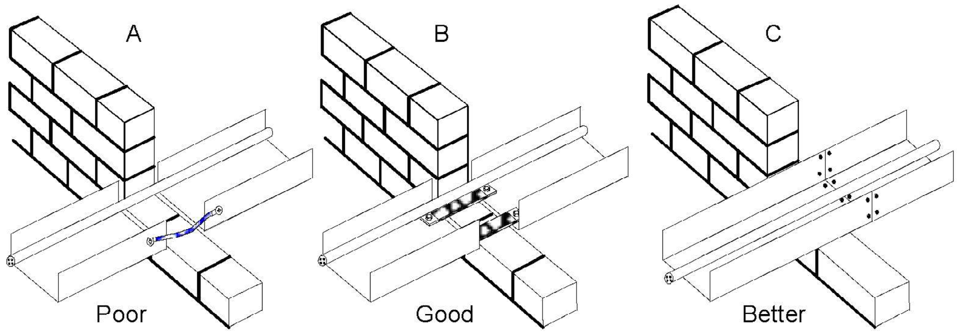


FIG. 55 CONNECTION OF METALLIC SECTIONS

4.5.4.7.3.2 *Non-metallic cable management systems*

Where equipment connected to the cabling system by unscreened cables are not affected by low frequency disturbances, the performance of non-metallic cable management systems is improved by installing a single lead within it, as a by-pass equipotential bonding conductor. The lead shall be efficiently connected to the equipment earthing system at both ends (for example onto a metal panel of an equipment cabinet).

The by-pass equipotential bonding conductor shall be designed to withstand large common mode and diverted fault currents.

4.5.5 *Protection Against Undervoltage*

4.5.5.1 *General requirements*

4.5.5.1.1 Where a drop in voltage, or a loss and subsequent restoration of voltage could imply dangerous situations for persons or property, suitable precautions shall be taken. Also, precautions shall be taken where a part of the installation or current-using equipment may be damaged by a drop in voltage.

An undervoltage protective device is not required if damage to the installation or to current-using equipment is considered to be an acceptable risk, provided that no danger is caused to persons.

4.5.5.1.2 The operation of undervoltage protective devices may be delayed if the operation of the appliance protected allows without danger a brief interruption or loss of voltage.

4.5.5.1.3 If use is made of contactors, delay in their opening and reclosing shall not impede instantaneous disconnection by control or protective devices.

4.5.5.1.4 The characteristics of the undervoltage protective device shall be compatible with the requirements of the IS standards for starting and use of equipment.

4.5.5.1.5 Where the reclosure of a protective device is likely to create a dangerous situation, the reclosure shall not be automatic.

5 SELECTION AND ERECTION OF ELECTRICAL EQUIPMENT

5.1 Common Rules

Every item of equipment shall be selected and erected so as to allow compliance with the rules stated in the following clauses and the relevant rules of this standard.

5.1.1 *Compliance with Standards*

5.1.1.1 Every item of equipment shall comply with Indian Standards as are appropriate.

5.1.1.2 Where there are no applicable or Indian Standards, the item of equipment concerned shall be selected by special agreement between the person specifying the installation and the installer.

5.1.2 *Operational Conditions and External Influences*

5.1.2.1 *Operational conditions*

5.1.2.1.1 *Voltage*

Equipment shall be suitable for the nominal voltage (r.m.s. value for a.c.) of the installation.

If, in IT installations, the neutral conductor is distributed, equipment connected between phase and neutral shall be insulated for the voltage between phases.

NOTE — For certain equipment, it may be necessary to take account of the highest and/or lowest voltage likely to occur in normal service.

5.1.2.1.2 *Current*

Equipment shall be selected for the design current (r.m.s. value for a.c.) which it has to carry in normal service.

Equipment shall also be capable of carrying the currents likely to flow in abnormal conditions for such periods of time as are determined by the characteristics of the protective devices.

5.1.2.1.3 *Frequency*

If frequency has an influence on the characteristics of equipment, the rated frequency of the equipment shall correspond to the frequency of the current in the circuit concerned.

5.1.2.1.4 *Power*

Equipment selected for its power characteristics shall be suitable for the normal operational conditions taking account of the load factor.

5.1.2.1.5 *Compatibility*

Unless other suitable precautions are taken during erection, all equipment shall be selected so that it will not cause harmful effects on other equipment nor impair the supply during normal service, including switching operations.

5.1.2.2 *External influences*

5.1.2.2.1 Electrical equipment shall be selected and erected in accordance with the requirements of Table 7, which indicates the characteristics of equipment necessary according to the external influences to which the equipment may be subjected.

Equipment characteristics shall be determined either by a degree of protection or by conformity to tests.

5.1.2.2.2 If the equipment does not, by its construction, have the characteristics relevant to the external influences of its location, it may nevertheless be used on condition that it is provided with appropriate additional protection in the erection of the installation. Such protection shall not adversely affect the operation of the equipment thus protected.

5.1.2.2.3 When different external influences occur simultaneously, they may have independent or mutual effect and the degree of protection shall be provided accordingly.

5.1.2.2.4 The selection of equipment according to external influences is necessary not only for proper functioning, but also to ensure the reliability of the measures of protection for safety complying with the rules of this standard generally. Measures of protection afforded by the construction of equipment are valid only for the given conditions of external influence if the corresponding equipment specification tests are made in these conditions of external influence.

NOTES

1 For the purposes of this standard, the following classes of external influences are conventionally regarded as normal:

AA Ambient temperature	AA4
AB Atmospheric humidity	AB4
Other environmental conditions (AC to AR)	XX1 of each parameter
Utilization and construction of buildings (B and C)	XX1 of each parameter, except XX2 for the parameter BC

2 The word "normal" appearing in the third column of the table signifies that the equipment must generally satisfy applicable IS standards.

5.1.3 *Accessibility*

5.1.3.1 *General*

All equipment, including wiring, shall be arranged so as to facilitate its operation, inspection and maintenance and access to its connections. Such facilities shall not be significantly impaired by mounting equipment in enclosures or compartments.

5.1.4 *Identification*

5.1.4.1 *General*

Labels or other suitable means of identification shall be provided to indicate the purpose of switchgear and controlgear, unless there is no possibility of confusion.

Where the functioning of switchgear and controlgear cannot be observed by the operator and where this might cause a danger, a suitable indicator, complying where applicable with IEC 60073 and IEC 60447, shall be fixed in a position visible to the operator.

5.1.4.2 *Wiring systems*

Wiring shall be so arranged or marked that it can be identified for inspection, testing, repairs or alteration of the installation.

5.1.4.3 *Identification of neutral and protective conductors*

5.1.4.3.1 The identification of separate neutral and protective conductors shall comply with IEC 60446.

5.1.4.3.2 PEN conductors, when insulated, shall be marked by one of the following methods:

a) green/yellow throughout their length with, in addition, light blue markings at the terminations, or
b) light blue throughout their length with, in addition, green/yellow markings at the terminations.

NOTE — The choice of method or methods is made by national committees.

5.1.4.4 *Protective devices*

The protective devices shall be arranged and identified so that the circuits protected may be easily recognized; for this purpose it may be convenient to group them in distribution boards.

5.1.4.5 *Diagrams*

5.1.4.5.1 Where appropriate, diagrams, charts or tables

Table 7 Characteristics of External Influences
(*Clauses* 4.3.2.3, 4.3.2.4 *and* 5.1.2.2.1)

Code	External Influences						Characteristics Required for Selection and Erection of Equipment	Reference
(1)	(2)						(3)	(4)
A	*Environmental conditions*							
AA	*Ambient temperature* The ambient temperature is that of the ambient air where the equipment is to be installed It is assumed that the ambient temperature includes the effects of other equipment installed in the same location The ambient temperature to be considered for the equipment is the temperature at the place where the equipment is to be installed resulting from the influence of all other equipment in the same location, when operating, not taking into account the thermal contribution of the equipment to be installed Lower and upper limits of ranges of ambient temperature:							
AA1	–60 °C +5 °C						Specially designed equipment or appropriate arrangements[1]	IS 13736 (All Parts)
AA2	–40 °C +5 °C							
AA3	–25 °C +5 °C						Normal (in certain cases special precautions may be necessary)	
AA4	–5 °C +40 °C							
AA5	+5°C +40 °C						Normal	
AA6	+5 °C +60 °C						Specially designed equipment or appropriate arrangements[1]	IS 13736 (All Parts)
AA7	–25 °C +55 °C						Specially designed equipment or appropriate arrangements[1]	
AA8	–50 °C +40 °C Ambient temperature classes are applicable only where humidity has no influence. The average temperature over a 24 h period must not exceed 5 °C below the upper limits. Combination of two ranges to define some environments may be necessary. Installations subject to temperatures outside the ranges require special consideration.							
AB	*Atmospheric humidity*							
	Air Temperature °C		**Relative Humidity** %		**Absolute Humidity** g/m^3			
	Low	High	Low	High	Low	High		
AB1	–60	+5	3	100	0.003	7	Indoor and outdoor locations with extremely low ambient temperatures Appropriate arrangements shall be made[3]	IS 13736 (All Parts)
AB2	–40	+5	10	100	0.1	7	Indoor and outdoor locations with low ambient	IS 13736 (All Parts)

Table 7 — (*Continued*)

Code	External Influences						Characteristics Required for Selection and Erection of Equipment	Reference
(1)	(2)						(3)	(4)
							temperatures Appropriate arrangements shall be made[3]	
	Air Temperature °C		**Relative Humidity** %		**Absolute Humidity** g/m³			
	Low	High	Low	High	Low	High		
AB3	-25	+5	10	100	0.5	7	Indoor and outdoor locations with low ambient temperatures Appropriate arrangements shall be made[3]	IS 13736 (All Parts)
AB4	-5	+40	5	95	1	29	Weather protected locations having neither temperature nor humidity control. Heating may be used to raise low ambient temperatures Normal [2]	IS 13736 (All Parts)
AB5	+5	+40	5	85	1	25	Weather protected locations with temperature control Normal [2]	IS 13736 (All Parts)
AB6	+5	+60	10	100	1	35	Indoor and outdoor locations with extremely high ambient temperatures, influence of cold ambient temperatures is prevented. Occurrence of solar and heat radiation Appropriate arrangements shall be made [3]	IS 13736 (All Parts)
AB7	-25	+55	10	100	0.5	29	Indoor weather-protected locations having neither temperature nor humidity control; the locations may have openings directly to the open air and be subjected to solar radiation Appropriate arrangements shall be made [3]	IS 13736 (All Parts)
AB8	-50	+40	15	100	0.04	36	Outdoor and non-weather protected locations, with low and high temperatures Appropriate arrangements shall be made [3]	IS 13736 (All Parts)

NOTES

1 All specified values are maximum or limit values which will have a low possibility of being exceeded**.**

2 The low and high relative humidities are limited by the low and high absolute humidities, so that, for example, for environmental parameters a and c, or b and d, the limit values given do not occur simultaneously. Therefore, Annex B contains climatograms which describes the interdependence of air temperature, relative humidity and absolute humidity for the climatic classes specified.

Code	External Influences	Characteristics Required for Selection and Erection of Equipment	Reference
AC	*Altitude*		
AC1	≤2 000 m	Normal[2]	
AC2	>2 000 m	May necessitate special precautions such as the application of derating factors For some equipment special arrangements may be necessary at altitudes of 1 000 m and above	

Table 7 — (*Continued*)

Code	External Influences	Characteristics Required for Selection and Erection of Equipment	Reference
AD	*Presence of water*		
AD1	Negligible	Probability of presence of water is negligible Location in which the walls do not generally show traces of water but may do so for short periods, for example in the form of vapour which good ventilation dries rapidly IPX0	IS 13736 (All Parts) IS/IEC 60529
AD2	Free-falling drops	Possibility of vertically falling drops Location in which water vapour occasionally condenses as drops or where steam may occasionally be present IPX1 or IPX2	IS 13736 (All Parts) IS/IEC 60529
AD3	Sprays	Possibility of water falling as a spray at an angle up to 60° from the vertical Locations in which sprayed water forms a continuous film on floors and/or walls IPX3	IS 13736 (All Parts) IS/IEC 60529
AD4	Splashes	Possibility of splashes from any direction Locations where equipment may be subjected to splashed water; this applies, for example, to certain external luminaires, construction site equipment IPX4	IS 13736 (All Parts) IS/IEC 60529
AD5	Jets	Possibility of jets of water from any direction Locations where hot water is used regularly (yards, car-washing bays) IPX5	IS 13736 (All Parts) IS/IEC 60529
AD6	Waves	Possibility of water waves Seashore locations such as piers, beaches, quays, etc. IPX6	IS 13736 (All Parts) IS/IEC 60529
AD7	Immersion	Possibility of intermittent partial or total covering by water Locations which may be flooded and/or where the equipment is immersed as follows: — Equipment with a height of less than 850 mm is located in such a way that its lowest point is not more than 1 000 mm below the surface of the water — Equipment with a height equal to or greater than 850 mm is located in such a way that its highest point is not more than 150 mm below the surface of the water IPX7	IS/IEC 60529
AD8	Submersion	Possibility of permanent and total covering by water Locations such as swimming pools where electrical equipment is permanently and totally covered with water under a pressure greater than 10 kPa IPX8	IS/IEC 60529
AE	*Presence of foreign solid bodies or dust*		
AE1	Negligible	The quantity or nature of dust or foreign solid bodies is not significant IP0X	IS 13736 (All Parts) IS/IEC 60529
AE2	Small objects (2.5 mm)	Presence of foreign solid bodies where the smallest dimension is not less than 2.5 mm IP3X Tools and small objects are examples of foreign solid bodies of which the smallest dimension is at least 2.5 mm	IS 13736 (All Parts) IS/IEC 60529

Table 7 — (*Continued*)

Code	External Influences	Characteristics Required for Selection and Erection of Equipment	Reference
AE3	Very small objects (1 mm)	Presence of foreign solid bodies where the smallest dimension is not less than 1 mm IP4X Wires are examples of foreign solid bodies of which the smallest dimension is not less than 1 mm	IS 13736 (All Parts) IS/IEC 60529
AE4	Light dust	Presence of light deposits of dust: 10<deposit of dust ≤ 35 mg/m² a day IP5X or equipment IP6X if dust should not penetrate equipment	IS 13736 (All Parts) IS/IEC 60529
AE5	Moderate dust	Presence of medium deposits of dust: 35 < deposit of dust ≤ 350 mg/m² a day IP5X or equipment IP6X if dust should not penetrate equipment	IS 13736 (All Parts) IEC 60529
AE6	Heavy dust	Presence of large deposits of dust: 350 < deposit of dust ≤ 1 000 mg/m² a day IP6X	IS 13736 (All Parts) IS/IEC 60529
AF	*Presence of corrosive or polluting substances*		
AF1	Negligible	The quantity or nature of corrosive or polluting substances is not significant Normal[2]	IS 13736 (All Parts)
AF2	Atmospheric	The presence of corrosive or polluting substances of atmospheric origin is significant Installations situated by the sea or near industrial zones producing serious atmospheric pollution, such as chemical works, cement works; this type of pollution arises especially in the production of abrasive, insulating or conductive dusts According to the nature of substances [for example, satisfaction of salt mist test according to IS 9000 (Part 11)].	IS 13736 (All Parts)
AF3	Intermittent or accidental	Intermittent or accidental subjection to corrosive or polluting chemical substances being used or produced Locations where some chemicals products are handled in small quantities and where these products may come only accidentally into contact with electrical equipment; such conditions are found in factory laboratories, other laboratories or in locations where hydrocarbons are used (boiler-rooms, garages, etc) Protection against corrosion according to equipment specification	IS 13736 (All Parts)
AF4	Continuous	Continuously subject to corrosive or polluting chemical substances in substantial quantity, for example, chemical works Equipment specially designed according to the nature of substances	IS 13736 (All Parts)
AG	*Mechanical shock* (*see* Annex N)		
AG1	Low severity	Normal, for example, household and similar equipment	IS 13736 (All Parts)
AG2	Medium severity	Standard industrial equipment, where applicable, or reinforced protection	IS 13736 (All Parts)
AG3	High severity	Reinforced protection	IS 13736 (All Parts)
AH	*Vibration* (*see* Annex N)		
AH1	Low severity	Household and similar conditions where the effects of vibration are generally negligible	IS 13736 (All Parts)

Table 7 — (*Continued*)

Code	**External Influences**	**Characteristics Required for Selection and Erection of Equipment**	**Reference**
		Normal [1]	
AH2	Medium severity	Usual industrial conditions Specially designed equipment or special arrangements	IS 13736 (All Parts)
AH3	High severity	Industrial installations subject to severe conditions Specially designed equipment or special arrangements	IS 13736 (All Parts)
AK	*Presence of flora and/or moulds growth*		
AK1	No hazard	No harmful hazard from flora and/or mould growth. Normal [4]	IS 13736 (All Parts)
AK2	Hazard	Harmful hazard from flora and/or mould growth. The hazard depends on local conditions and the nature of flora. Distinction should be made between harmful growth of vegetation or conditions for promotion of mould growth Special protection, such as: – increased degree of protection (*see* AE) – special materials or protective coating of enclosures – arrangements to exclude flora from location	IS 13736 (All Parts)
AL	*Presence of fauna*		
AL1	No hazard	No harmful hazard from fauna Normal [2]	IS 13736 (All Parts)
AL2	Hazard	Harmful hazard from fauna (insects, birds, small animals) The hazard depends on the nature of the fauna. Distinction should be made between: – presence of insects in harmful quantity or of an aggressive nature; – presence of small animals or birds in harmful quantity or of an aggressive nature Protection may include: – an appropriate degree of protection against penetration of foreign solid bodies (*see* AE); – sufficient mechanical resistance (*see* AG); – precautions to exclude fauna from the location (such as cleanliness, use of pesticides); – special equipment or protective coating of enclosures	IS 13736 (All Parts)
AM	*Electromagnetic, electrostatic, or ionising influences* [*see* IEC 61000-2 series and IS 14700 (Part 4 /Section2)]		
	Low-frequency electromagnetic phenomena (*conducted or radiated)*		
	Harmonics, interharmonics		
AM1-1	Controlled level	Care should be taken that the controlled situation is not impaired	
AM1-2	Normal level	Special measures in the design of the installation, for example, filters	Complying with Table 1 of IEC 61000-2-2
AM1-3	High level		Locally higher than Table 1 of IEC 61000-2-2
	Signalling voltages		
AM-2-1	Controlled level	Possibly: blocking circuits	Lower than specified below
AM-2-2	Medium level	No additional requirement	IEC 61000-2-1 and
AM-2-3	High level	Appropriate measures	IEC 61000-2-2
	Voltage amplitude variations		
AM-3-1	Controlled level		
AM-3-2	Normal level	Compliance with **4.5**	
AM-4	*Voltage unbalance*		Compliance with IEC 61000-2-2
AM-5	*Power frequency variations*		±1 Hz according to IEC 61000-2-2
AM-6	No classification	*See* **4.5** High withstand of signal and control systems of switchgear and controlgear	ITU-T
AM-7	*Direct current in a.c. network*		
	No classification	*Measures to limit their presence in level and time in the current-using equipment or their vicinity*	

Table 7 — (*Continued*)

Code	External Influences	Characteristics Required for Selection and Erection of Equipment	Reference
	Radiated magnetic fields		
AM-8-1	Medium level	Normal 2	Level 2 of IS 14700 (Part 4/Section 8)
AM-8-2	High level	Protection by appropriate measures, for example, screening and/or separation	Level 4 of IS 14700 (Part 4/Section 8)
	Electric fields		
AM-9-1	Negligible level	Normal2	
AM-9-2	Medium level	*See* IEC 61000-2-5	IEC 61000-2-5
AM-9-3	High level	*See* IEC 61000-2-5	
AM-9-4	Very high level	*see* IEC 61000-2-5	
	High-frequency electromagnetic phenomena conducted, induced or radiated (*continuous or transient*)		
	Induced oscillatory voltages or currents		
AM-21	No classification	Normal2	IS 14700 (Part 4/Sec 6)
	Conducted unidirectional transients of the nanosecond time scale		IS 14700 (Part 4/Sec 4)
AM-22-1	Negligible level	Protective measures are necessary	Level 1
AM-22-2	Medium level	Protective measures are necessary (*see* **5.1.2.2**)	Level 2
AM-22-3	High level	Normal equipment	Level 3
AM-22-4	Very high level	High immunity equipment	Level 4
	Conducted unidirectional transients of the microsecond to the millisecond time scale		
AM-23-1 AM-23-2 AM-23-3	Controlled level Medium level High level	Impulse withstand of equipment and overvoltage protective means chosen taking into account the nominal supply voltage and the impulse withstand category according to **4.5**	**4.5.4** **4.5.4**
	Conducted oscillatory transients		
AM-24-1	Medium level	*see* IS 14700 (Part 4/Sec 12)	IS 14700 (Part 4/Sec 12)
AM-24-2	High level	*see* IEC 60255-22-1	IEC 60255-22-1
	Radiated high-frequency phenomena		IS 14700 (Part 4/Sec 3)
AM-25-1	Negligible level		Level 1
AM-25-2	Medium level	Normal2	Level 2
AM-25-3	High level	Reinforced level	Level 3
	Electrostatic discharges		IS 14700 (Part 4/Sec 2)
AM-31-1	Small level	Normal2	Level 1
AM-31-2	Medium level	Normal2	Level 2
AM-31-3	High level	Normal2	Level 3
AM-31-4	Very high level	Reinforced	Level 4
AM-41-1	*Ionization* No classification	Special protection such as: – Spacing from source – Interposition of screens, enclosure by special materials	
AN	*Solar radiation*		
AN1	Low	Intensity ≤ 500 W/m² Normal 2	IS 13736 (Part 3/Sec 3)
AN2	Medium	500 W/m² < intensity ≤ 700 W/m² Appropriate arrangements shall be made 3	IS 13736 (Part 3/Sec 3)
AN3	High	700 W/m² < Intensity ≤ 1 120 W/m² Appropriate arrangements shall be made 3 Such arrangements could be: – material resistant to ultra-violet radiation – special colour coating – interposition of screens	IS 13736 (Part 3/Sec 4)
AP	*Seismic effects*		
AP1	Negligible	Acceleration ≤ 30 Gal (1Gal = 1cm/s²)	

Table 7 — (*Continued*)

Code	External Influences	Characteristics Required for Selection and Erection of Equipment	Reference
		Normal	
AP2 AP3 AP4	Low severity Medium severity High severity	30 Gal < acceleration ≤ 300 Gal Under consideration 300 Gal < acceleration ≤ 600 Gal under consideration 600 Gal < acceleration Under consideration Vibration which may cause the destruction of the building is outside the classification Frequency is not taken into account in the classification; however, if the seismic wave resonates with the building, seismic effects must be specially considered. In general, the frequency of seismic acceleration is between 0 Hz and 10 Hz	
AQ	*Lightning*		
AQ1 AQ2 AQ3	Negligible Indirect exposure Direct exposure	≤ 25 days per year or result of risk assessment in accordance with **4.5.3** Normal > 25 days per year or result of risk assessment in accordance with **4.5.3** Normal Hazard from exposure of equipment If lightning protection is necessary, it shall be arranged according to IEC 61024-1	
AR	*Movement of air*		
AR1 AR2 AR3	Low Medium High	Speed ≤ 1 m/s Normal [2] 1 m/s < speed ≤ 5 m/s Appropriate arrangements shall be made [3] 5 m/s < speed ≤ 10 m/s Appropriate arrangements shall be made [3]	
AS	*Wind*		
AS1 AS2 AS3	Low Medium High	Speed ≤ 20 m/s Normal [2] 20 m/s < speed ≤ 30 m/s Appropriate arrangements shall be made [3] 30 m/s < speed ≤ 50 m/s Appropriate arrangements shall be made [3]	
B	*Utilization*		
BA	*Capability of persons*		
BA1 BA2	Ordinary Children	Uninstructed persons Normal [2] Locations intended for presence of groups of children [5] Nurseries Equipment of degrees of protection higher than IP2X. Socket outlets shall be provided with at least IP2X or IPXXB and with increased protection according to IS 1293 Inaccessibility of equipment with external surface temperature exceeding 80 °C (60 °C for nurseries and the like)	
BA3	Handicapped	Persons not in command of all their physical and intellectual abilities	

Table 7 — (*Continued*)

Code	External Influences	Characteristics Required for Selection and Erection of Equipment	Reference
		(sick persons, old persons) Hospitals According to the nature of the handicap	
BA4	Instructed	Persons adequately advised or supervised by skilled persons to enable them to avoid dangers which electricity may create (operating and maintenance staff) Electrical operating areas	
BA5	Skilled	Persons with technical knowledge or sufficient experience to enable them to avoid danger which electricity may create (engineers and technicians) Closed electrical operating areas	
BB	*Electrical resistance of the human body* (*under consideration)*		
BC	*Contact of persons with earth potential*		
		Class of equipment according to IEC 61140 0-0I I II III	
BC1	None	Persons in non-conducting situations: A Y A A	**4.2.13.3**
BC2	Low	Persons who do not in usual conditions make contact with extraneous-conductive-parts or stand on conducting surfaces: A A A A	
BC3	Frequent	Persons who are frequently in touch with extraneouss conductive parts or stands on conducting surfaces. Locations with extraneous-conductive-parts either numerous or of large area X A A A A Equipment permitted X Equipment prohibited Y Permitted if used as class 0	
BC4	Continuous	Persons who are immersed in water or in long term permanent contact with metallic surroundings and for whom the possibility of interrupting contact is limited Metallic surroundings such as boilers and tanks Under consideration	
BD	*Conditions of evacuation in an emergency*		
BD1	(Low density/easy exit)	Low density occupation, easy conditions of evacuation Buildings of normal or low height used for habitation. Normal	
BD2	(Low density/difficult exit)	Low density occupation, difficult conditions of evacuation High-rise buildings	
BD3	(High density/easy exit)	High density occupation, easy conditions of evacuation Locations open to the public (theatres, cinemas, departments stores, etc)	
BD4	(High density/difficult exit)	High density occupation, difficult conditions of evacuation High-rise buildings open to the public (hotels, hospitals, etc)	
BE	*Nature of processed or stored materials*		
BE1	No significant risks	Normal [2]	
BE2	Fire risks	Manufacture, processing or storage of flammable materials including	**4.3**

Table 7 — (*Concluded*)

Code	External Influences	Characteristics Required for Selection and Erection of Equipment	Reference
		presence of dust Barns, wood-working shops, paper factories Equipment made of material retarding the spread of flame. Arrangements such that a significant temperature rise or a spark within electrical equipment cannot initiate an external fire	**5.2**
BE3	Explosion risks	Processing or storage of explosive or low-flash-point materials including presence of explosive dusts Oil refineries, hydrocarbon stores Requirements for electrical apparatus for explosive atmospheres (*see* IS/IEC 60079)	Under consideration
BE4	Contamination risks	Presence of unprotected foodstuffs, pharmaceutics, and similar products without protection Foodstuff industries, kitchens: Certain precautions may be necessary, in the event of fault, to prevent processed materials being contaminated by electrical equipment, for example, by broken lamps Appropriate arrangements, such as: — protection against falling debris from broken lamps and other fragile objects; — screens against harmful radiation such as infra-red or ultra-violet	Under consideration
C	*Construction of buildings*		
CA	*Construction materials*		
CA1	Non combustible	Normal [2]	
CA2	Combustible	Buildings constructed mainly out of combustible materials Wooden buildings Under consideration	**4.3**
CB	*Building design*		
CB1	Negligible risks	Normal [2]	
CB2	Propagation of fire	Buildings of which the shape and dimensions facilitates the spread of fire (for example, chimney effects) High-rise buildings. Forced ventilation systems Equipment made of material retarding the propagation of fire including fires not originating from the electrical installation. Fire barriers [6]	**4.2** & **4.3**
CB3	Movement	Risk due to structural movement (for example, displacement between different parts of a building or between a building and the ground or building foundations Buildings of considerable length or erected on unstable ground Contraction or expansion joints in electrical wiring	Contraction or expansion joints (under consideration) **5.2**
CB4	Flexible or unstable	Structures which are weak or subject to movement (for example, oscillation) Tents, air-support structures, false ceilings, removable partitions. Installations to be structurally self-supporting Under consideration	Flexible wiring (under consideration) **5.2**

1 May necessitate certain supplementary precautions (for example, special lubrication).

2 This means that ordinary equipment will operate safely under the described external influences.

3 This means that special arrangements need to be made, for example, between the designer of the installation and the equipment manufacturer, for example, for specially designed equipment.

4 This means that ordinary equipment will operate safely under the described external influences.

5 This class does not necessarily apply to family dwellings.

6 Fire detectors may be provided.

in accordance with IEC 61346-1 and the IEC 61082 series shall be provided, indicating in particular:

a) the type and composition of circuits (points of utilization served, number and size of conductors, type of wiring); and
b) the characteristics necessary for the identification of the devices performing the functions of protection, isolation and switching and their locations.

For simple installations the foregoing information may be given in a schedule.

5.1.4.5.2 The symbols used shall be chosen from the IS 12032 series.

5.1.5 *Prevention of Mutual Detrimental Influence*

5.1.5.1 Equipment shall be so selected and erected as to avoid any harmful influence between the electrical installation and any non-electrical installations.

Equipment not provided with a back plate shall not be mounted on a building surface unless the following requirements are satisfied:

a) a voltage transfer to the building surface is prevented; and
b) fire segregation is provided between the equipment and a combustible building surface.

If the building surface is non-metallic and non-combustible, no additional measures are required. If not, these requirements may be satisfied by one of the following measures:

a) if the building surface is metallic, it shall be bonded to the protective conductor (PE) or to the equipotential bonding conductor of the installation, in accordance with **4.2.11.3.1.2** and **5.4**;
b) if the building surface is combustible, the equipment shall be separated from it by a suitable intermediate layer of insulating material having a flammability rating as per I
c) 1731.

5.1.5.2 Where equipment carrying currents of different types or at different voltages is grouped on a common assembly (such as a switchboard, a cubicle or a control desk or box), all the equipment belonging to any one type of current or any one voltage shall be effectively segregated wherever necessary to avoid mutual detrimental influence.

5.1.5.3 *Electromagnetic compatibility*

5.1.5.3.1 *Choice of the immunity and emission levels*

5.1.5.3.1.1 The immunity levels of equipment shall be taken into account the electromagnetic influences (*see* Table 7) that can occur when connected and erected as for normal use, and taking into account the intended level of continuity of service necessary for the application.

5.1.5.3.1.2 Equipment shall be chosen with sufficiently low emission levels so that it cannot cause electromagnetic interference by electrical conduction or propagation in the air with other electrical equipment inside or outside the building. If necessary, means of mitigation shall be installed to minimize the emission (*see* **4.5**).

5.1.6 *Measures Related To Protective Conductor Currents*

The protective conductor current generated by electrical equipment under normal conditions of operation and the design of electrical installations shall be compatible, in order to provide safety and to assure normal use.

The permissible protective conductor currents for equipment are specified in IEC 61140 and reproduced in Annex Q, and shall be taken into consideration when information is not available from the manufacturer.

NOTES

1 For the purposes of **5.1.6**, a protective conductor current is a current which flows in the protective conductor when the equipment is fault-free and operating normally.

2 For prevention of unwanted tripping of residual current devices due to protective conductor currents, *see* **5.3.2.2.1.3**.

3 The installer should inform the owner of the installation that preferably such equipment should be selected for which the manufacturer has provide information concerning the value of protective conductor current. Equipment with low values should be chosen to avoid unwanted tripping.

4 For reinforced protective conductors, *see* **5.4.3.7**.

5.1.6.1 *Transformer*

Measures may be taken in the electrical installation to restrict protective conductor currents by supplying limited areas with separate winding transformers.

5.1.6.2 *Signalling systems*

The use of any live conductor together with the protective conductor as a return path for signalling is not allowed.

NOTE — For the use of d.c. return conductors, see the requirements of **5.4.3.5**.

5.2 Selection and Erection of Electrical Equipment — Wiring Systems

5.2.1 *Void*

5.2.2 *Void*

5.2.3 *General*

Consideration shall be given to the application of the fundamental principles of this standard as it applies to:

a) cables and conductors,
b) their termination and/or jointing,
c) their associated supports or suspensions, and
d) their enclosure or methods of protection against external influences.

5.2.4 *Types of Wiring System*

5.2.4.1 The method of installation of a wiring system (excluding systems covered by **5.2.4.4**) in relation to the type of conductor or cable used shall be in accordance with Table 17, provided the external influences are taken into account according to **5.2.5**.

5.2.4.2 The method of installation of a wiring system (excluding systems covered by **5.2.4.4**) in relation to the situation concerned shall be in accordance with Table 18. Other methods of installation of cables, conductors and busbars not included in Table 18 are permitted, provided that they fulfil the requirements of this part.

5.2.4.3 Examples of wiring systems (excluding systems covered by **5.2.4.4**) together with reference to the method of installation to be used to obtain current-carrying capacity are shown in Table 19.

NOTE — Table 19 gives the reference method of installation where it is considered that the same current-carrying capacities can safely be used. It is not implied that all these items are necessarily recognized in national rules of all countries or that other methods of installation are prohibited.

5.2.4.4 *Busbar trunking systems and powertrack systems*

Busbar trunking systems shall comply with IS/IEC 60439-2 and powertrack systems shall comply with the IEC 61534 series. Busbar trunking systems and powertrack systems shall be selected and installed in accordance with manufacturers' instructions, taking account of external influences.

5.2.4.5 *a.c. circuits — Electromagnetic effects (prevention of eddy current)*

5.2.4.5.1 Conductors of a.c. circuits installed in ferromagnetic enclosures shall be arranged so that all conductors of each circuit, including the protective conductor of each circuit, are contained in the same enclosure. Where such conductors enter a ferrous enclosure, they shall be arranged such that the conductor are only collectively surrounded by ferromagnetic materials.

5.2.4.5.2 Single-core cables armoured with steel wire or steel tape shall not be used for a.c. circuits.

NOTE — The steel wire or steel tape armour of a single-core cable is regarded as a ferromagnetic enclosure. For single-core wire armoured cables, the use of aluminium armour is recommended.

5.2.4.6 *Conduit systems, cable ducting systems, cable trunking systems, cable tray systems and cable ladder systems*

Several circuits are allowed in the same conduit system, separated compartment of cable ducting system or cable trunking system provided all conductors are insulated for the highest nominal voltage present.

Conduit systems shall comply with the IS 14930 series, cable trunking or ducting systems shall comply with the IS 14297 series and cable tray and cable ladder systems shall comply with IEC 61537.

NOTE — Guidance on the selection of conduit systems is given in Annex W.

5.2.4.7 *Several circuits in one cable*

Several circuits are allowed in the same cable provided all conductors are insulated for the highest nominal voltage present.

5.2.4.8 *Circuit arrangements*

5.2.4.8.1 Conductors of a circuit shall not be distributed over different multi-core cables, conduits, cable ducting systems or cable trunking systems. This is not required where a number of multi-core cables, forming one circuit, are installed in parallel. Where multi-core cables are installed in parallel, each cable shall contain one conductor of each phase and the neutral, if any.

5.2.4.8.2 The use of a common neutral conductor for several main circuits is not permitted. However, single-phase a.c. final circuits may be formed from one line conductor and the neutral conductor of one multi-phase a.c. circuit with only one neutral conductor provided that the arrangement of the circuits remains recognizable. This multi-phase circuit shall be isolated by means of an isolating device according to **5.3.7.3.2** which isolates all live conductors.

NOTE — For the allocation of a common protective conductor for several circuits (*see* **5.3**).

5.2.4.8.3 Where several circuits are terminated in a single junction box the terminals for each circuit shall be separated by insulating partitions, except for connecting devices in accordance with the IEC 60998 series, and terminal blocks in accordance with IEC 60947-7.

5.2.4.9 *Use of flexible cables or cords*

5.2.4.9.1 A flexible cable may be used for fixed wiring where the provisions of this standard are met.

5.2.4.9.2 Equipment that is intended to be moved in use shall be connected by flexible cables or cords, except equipment supplied by contact rails.

5.2.4.9.3 Stationary equipment which is moved temporarily for the purpose of connecting, cleaning etc, for example, cookers or flush-mounting units for installations in false floors, shall be connected with flexible cables or cords.

5.2.4.9.4 Flexible conduit systems may be used to protect flexible insulated conductors.

5.2.4.10 *Installation of cables*

Insulated conductors (non-sheathed) for fixed wiring shall be enclosed in conduit, cable ducting system or cable trunking system. This requirement does not apply to a protective conductor complying with **5.4**.

5.2.5 *Selection and Erection of Wiring Systems in Relation to External Influences*

The installation method selected shall be such that protection against the expected external influences is ensured in all appropriate parts of the wiring system. Particular care shall be taken at changes in direction and where wiring enters into equipment.

NOTE — The external influences categorized in Table 7 which are of significance to wiring systems are included in this clause.

5.2.5.1 *Ambient temperature* (*AA*)

5.2.5.1.1 Wiring systems shall be selected and erected so as to be suitable for any temperature between the highest and the lowest local ambient temperature and to ensure that the limiting temperature in normal operation (*see* Table 8) and the limiting temperature in case of a fault will not be exceeded.

NOTE — "Limiting temperature" means maximum continuous operating temperature.

5.2.5.1.2 Wiring system components including cables and wiring accessories shall only be installed or handled at temperatures within the limits stated in the relevant product standard or as given by the manufacturer.

5.2.5.2 *External heat sources*

5.2.5.2.1 In order to avoid the harmful effects of heat from external sources, one or more of the following methods or an equally effective method shall be used to protect wiring systems:

- heat shielding;
- placing sufficiently far from the source of heat;
- selecting of the wiring system components with due regard for the additional temperature rise which may occur;
- local reinforcement of insulating material, for example, by heat-resisting insulated sleeving.

NOTE — Heat from external sources may be radiated, convected or conducted, for example,

a) from hot water systems,
b) from plant, appliances and luminaires,
c) from manufacturing processes,
d) through heat conducting materials, and
e) from solar gain of the wiring system or its surrounding medium.

5.2.5.3 *Presence of water* (*AD) or high humidity* (*AB)*

5.2.5.3.1 Wiring systems shall be selected and erected so that no damage is caused by condensation or ingress of water. The completed wiring system shall comply with the IP degree of protection relevant to the particular location.

NOTE — In general, the sheaths and insulation of cables for fixed installations may be regarded, when intact, as proof against penetration by moisture. Special considerations apply to cables liable to frequent splashing, immersion or submersion.

5.2.5.3.2 Where water may collect or condensation may form in wiring systems, provision shall be made for its escape.

5.2.5.3.3 Where wiring systems may be subjected to waves (AD6), protection against mechanical damage shall be afforded by one or more of the methods of **5.2.5.6**, **5.2.5.7** and **5.2.5.8**.

5.2.5.4 *Presence of solid foreign bodies* (*AE)*

5.2.5.4.1 Wiring systems shall be selected and erected so as to minimize the danger arising from the ingress of solid foreign bodies. The completed wiring system shall comply with the IP degree of protection relevant to the particular location.

5.2.5.4.2 In a location where dust in significant quantity is present (AE4), additional precautions shall be taken to prevent the accumulation of dust or other substances in quantities which could adversely affect the heat dissipation from the wiring system.

NOTE — A wiring system which facilitates the removal of dust may be necessary (*see* **5.2.12**).

5.2.5.5 *Presence of corrosive or polluting substances* (*AF*)

5.2.5.5.1 Where the presence of corrosive or polluting substances, including water, is likely to give rise to corrosion or deterioration, parts of the wiring system likely to be affected shall be suitably protected or manufactured from a material resistant to such substances.

NOTE — Suitable protection for application during erection may include protective tapes, paints or grease. These measures should be coordinated with the manufacturer.

5.2.5.5.2 Dissimilar metals, liable to initiate electrolytic action, shall not be placed in contact with each other unless special arrangements are made to avoid the consequences of such contact.

5.2.5.5.3 Materials liable to cause mutual or individual

deterioration or hazardous degradation shall not be placed in contact with each other.

5.2.5.6 *Impact* (*AG)*

5.2.5.6.1 Wiring systems shall be selected and erected so as to minimize the damage arising from mechanical stress, for example, by impact, penetration or compression during installation, use or maintenance.

5.2.5.6.2 In fixed installations where impacts of medium severity (AG2) or high severity (AG3) can occur, protection shall be afforded by:

a) the mechanical characteristics of the wiring system, or
b) the location selected, or
c) the provision of additional local or general mechanical protection, or
d) by any combination of the above.

NOTES

1 Examples are areas where the floor is likely to be penetrated and areas used by forklift trucks.

2 Additional mechanical protection may be achieved by using suitable cable trunking/ducting or conduit systems.

5.2.5.6.3 A cable installed under a floor or above a ceiling shall be run in such a position that it is not liable to be damaged by contact with the floor or the ceiling or their fixings.

5.2.5.6.4 The degree protection of electrical equipment shall be maintained after installation of the cables and conductors.

5.2.5.7 *Vibration* (*AH)*

5.2.5.7.1 Wiring systems supported by or fixed to structures of equipment subject to vibration of medium severity (AH2) or high severity (AH3) shall be suitable for such conditions, particularly where cables and cable connections are concerned.

NOTE — Special attention should be paid to connections to vibrating equipment. Local measures may be adopted such as flexible wiring systems.

5.2.5.7.2 The fixed installation of suspended current-using equipment, for example, luminaires, shall be connected by cable with flexible cores. Where no vibration or movement can be expected, cable with non-flexible core may be used.

5.2.5.8 *Other mechanical stresses* (*AJ)*

5.2.5.8.1 Wiring systems shall be selected and erected so as to avoid during installation, use or maintenance, damage to cables and insulated conductors and their terminations.

The use of lubricants containing silicone oil for threading in cables and conductors into conduit systems, ducting systems, trunking systems and tray and ladder systems is not allowed.

5.2.5.8.2 Where buried in the structure, conduit systems or cable ducting systems, other than pre-wired conduit assemblies specifically designed for the installation, shall be completely erected between access points before any insulated conductor or cable is drawn in.

5.2.5.8.3 The radius of every bend in a wiring system shall be such that conductors or cables do not suffer damage and terminations are not stressed.

5.2.5.8.4 Where the conductors or cables are not supported continuously due to the method of installation, they shall be supported by suitable means at appropriate intervals in such a manner that the conductors or cables do not suffer damage by their own weight, or due to electro-dynamic forces resulting from short-circuit current.

NOTE — Precautions due to electro-dynamic forces resulting from short-circuit currents need only be taken on single-core cables with a cross-sectional area greater than 50 mm^2.

5.2.5.8.5 Where the wiring system is subjected to a permanent tensile stress (for example, by its own weight in vertical runs) a suitable type of cable or conductor with appropriate cross-sectional areas and method of mounting shall be selected in such a manner that the conductors or cables do not suffer damage by unacceptable tensile stress.

5.2.5.8.6 Wiring systems intended for the drawing in or out of conductors or cables shall have adequate means of access to allow this operation.

5.2.5.8.7 Wiring systems buried in floors shall be sufficiently protected to prevent damage caused by the intended use of the floor.

5.2.5.8.8 Wiring systems which are rigidly fixed and buried in the walls shall be run horizontally, vertically or parallel to the room edges.

Wiring systems in ceilings or in floors may follow the shortest practical route.

5.2.5.8.9 Wiring systems shall be installed so that mechanical stress to the conductors and connections is avoided.

5.2.5.8.10 Cables, conduits or ducts that are buried in the ground shall either be provided with protection against mechanical damage or be buried at a depth that minimizes the risk of such damage. Buried cables shall be marked by cable covers or a suitable marking tape. Buried conduits and ducts shall be suitably identified.

NOTES

1 IS 14930 (Parts 1 & 2) is the standard for buried under ground conduits.

2 Mechanical protection may be achieved by using conduit systems buried underground according to IS 14930 (Parts 1 & 2) or armoured cables or other appropriate methods such as cover plates.

5.2.5.8.11 Cable supports and enclosures shall not have sharp edges liable to damage the cables or insulated conductors.

5.2.5.8.12 Cables and conductors shall not be damaged by the fixing means.

5.2.5.8.13 Cables, busbars and other electrical conductors which pass across expansion joints shall be so selected and erected that anticipated movement does not cause damage to the electrical equipment, for example, by use of flexible wiring system.

5.2.5.8.14 Where wiring passes through fixed partitions, it shall be protected against mechanical damage, for example, metallic sheathed or armoured cables, or by use of conduit or grommets.

NOTE — No wiring system should penetrate an element of building construction which is intended to be load-bearing unless the integrity of the load-bearing element can be assured after such penetration.

5.2.5.9 *Presence of flora and/or mould growth* (*AK*)

5.2.5.9.1 Where the conditions experienced or expected constitute a hazard (AK2), the wiring system shall be selected accordingly or special protective measures shall be adopted.

NOTES

1 An installation method which facilitates the removal of such growths may be necessary (*see* **5.2.12**).

2 Possible preventive measures are closed types of installation (conduit or cable ducting or cable trunking), maintaining distances to plants and regular cleaning of the relevant wiring system.

5.2.5.10 *Presence of fauna* (*AL*)

Where conditions experienced or expected constitute a hazard (AL2), the wiring system shall be selected accordingly or special protective measures shall be adopted, for example, by

a) the mechanical characteristics of the wiring system, or
b) the location selected, or
c) the provision of additional local or general mechanical protection, or
d) by any combination of the above.

5.2.5.11 *Solar radiation* (*AN*) *and ultraviolet radiation*

Where significant solar radiation (AN2) or ultraviolet radiation is experienced or expected, a wiring system suitable for the conditions shall be selected and erected or adequate shielding shall be provided. Special precautions may need to be taken for equipment subject to ionizing radiation.

NOTE — *See also* **5.2.5.2.1** dealing with temperature rise.

5.2.5.12 *Seismic effects* (*AP*)

5.2.5.12.1 The wiring system shall be selected and erected with due regard to the seismic hazards of the location of the installation.

5.2.5.12.2 Where the seismic hazards experienced are low severity (AP2) or higher, particular attention shall be paid to the following:

a) the fixing of wiring systems to the building structure; and
b) the connections between the fixed wiring and all items of essential equipment, for example, safety services, shall be selected for their flexible quality.

5.2.5.13 *Wind* (*AR*)

5.2.5.13.1 *See* **5.2.5.7**, Vibration (AH), and **5.2.5.8**, Other mechanical stresses (AJ).

5.2.5.14 *Nature of processed or stored materials* (*BE*)

See **4.3.2**, measures for protection against fire, and **5.2.10**, Selection and erection of wiring systems to minimize the spread of fire.

5.2.5.15 *Building design* (*CB*)

5.2.5.15.1 Where risks due to structural movement exist (CB3), the cable support and protection system employed shall be capable of permitting relative movement so that conductors and cables are not subjected to excessive mechanical stress.

5.2.5.15.2 For flexible structures or structures intended to move (CB4), flexible wiring systems shall be used.

5.2.6 *Current-Carrying Capacities*

5.2.6.1 The current to be carried by any conductor for sustained periods during normal operation shall be such that the temperature limit of the insulation is not exceeded. This requirement is fulfilled by application of Table 8, for the types of insulation given in this table. The value of current shall be selected in accordance with **5.2.6.2** or determined in accordance with **5.2.5.3**.

5.2.6.2 The requirement of **5.2.6.1** is considered to be satisfied if the current for insulated conductors and cables without armour does not exceed the appropriate values selected from the tables in Annex S with reference to Table 19, subject to any necessary correction factors given in Annex S. The current-carrying capacities given in Annex S are provided for guidance.

NOTE — It is recognized that there will be some tolerance in the current-carrying capacities depending on the environmental conditions and the precise construction of the cables.

5.2.6.3 The appropriate values of current-carrying capacity may also be determined as described in the IEC 60287 series, or by test, or by calculation using a

Table 8 Maximum Operating Temperatures for Types of Insulation
(*Clauses* 5.2.5.1.1 *and* 5.2.6.1)

Type of Insulation	Temperature Limit[1), 4)] °C
Thermoplastic (PVC)	70 at the conductor
Thermosetting (XLPE or EPR rubber)	90 at the conductor[2)]
Mineral (thermoplastic (PVC) covered or bare exposed to touch)	70 at the sheath
Mineral (bare not exposed to touch and not in contact with combustible material)	105 at the sheath[2), 3)]

1) The maximum permissible conductor temperatures given in Table 8 on which the tabulated current-carrying capacities given in Annex A are based, have been taken from IEC 60502 and IEC 60702and are shown on these tables.
2) Where a conductor operates at a temperature exceeding 70 °C, it shall be ascertained that the equipment connected to the conductor is suitable for the resulting temperature at the connection.
3) For mineral insulated cables, higher operating temperatures may be permissible dependent upon the temperature rating of the cable, its terminations, the environmental conditions and other external influences.
4) Where certified, conductors or cable may have maximum operating temperature limits in accordance with the manufacturer's specification.

NOTES
1 The table does not include all types of cables.
2 This does not apply to busbar trunking systems or powertrack systems or lighting track systems for which the current-carrying capacity should be provided by the manufacturer according to IS 8623 (Part 2) and powertrack systems to IEC 61534-1.
3 For the temperature limit for other types of insulation, please refer to cable specification or manufacturer.

recognized method, provided that the method is stated. Where appropriate, account shall be taken of the characteristics of the load and, for buried cables, the effective thermal resistance of the soil.

5.2.6.4 The ambient temperature is the temperature of the surrounding medium when the cable(s) or insulated conductor(s) under consideration are not loaded.

5.2.6.5 *Groups containing more than one circuit*

The group reduction factors (Tables 36 to Table 40), are applicable to groups of insulated conductors or cables having the same maximum operating temperature.

For groups containing cables or insulated conductors having different maximum operating temperatures, the current-carrying capacity of all the cables or insulated conductors in the group shall be based on the lowest maximum operating temperature of any cable in the group, together with the appropriate group reduction factor.

If, due to known operating conditions, a cable or insulated conductor is expected to carry a current not greater than 30 percent of its grouped current-carrying capacity, it may be ignored for the purpose of obtaining the reduction factor for the rest of the group.

5.2.6.6 *Number of loaded conductors*

5.2.6.6.1 The number of conductors to be considered in a circuit are those carrying load current. Where it can be assumed that conductors in polyphase circuits carry balanced currents, the associated neutral conductor need not be taken into consideration. Under these conditions, a four-core cable is given the same current-carrying capacity as a three-core cable having the same conductor cross-sectional area for each line conductor. Four- and five-core cables may have higher current-carrying capacities when only three conductors are loaded. This assumption is not valid in the case of the presence of third harmonic or multiples of 3 presenting a THD (total harmonic distortion) greater than 15 percent.

5.2.6.6.2 Where the neutral conductor in a multicore cable carries current as a result of an imbalance in the line currents, the temperature rise due to the neutral current is offset by the reduction in the heat generated by one or more of the line conductors. In this case, the neutral conductor size shall be chosen on the basis of the highest line current.

In all cases, the neutral conductor shall have a cross-sectional area adequate to afford compliance with **5.2.6.1**.

5.2.6.6.3 Where the neutral conductor carries current without a corresponding reduction in load of the line conductors, the neutral conductor shall be taken into account in ascertaining the current-carrying capacity of the circuit. Such currents may be caused by a significant triple harmonic current in three-phase circuits. If the harmonic content is greater than 15 percent of the fundamental line current, the neutral conductor size shall not be smaller than that of the line conductors. Thermal effects due to the presence of third harmonic or multiples of 3 and the corresponding reduction factors for higher harmonic currents are given in Annex V.

5.2.6.6.4 Conductors which serve the purpose of protective conductors only (PE conductors) shall not

be taken into consideration. PEN conductors shall be taken into consideration in the same way as neutral conductors.

5.2.6.7 *Conductors in parallel*

Where two or more live conductors or PEN conductors are connected in parallel in a system, either:

a) measures shall be taken to achieve equal load current sharing between them;

   This requirement is considered to be fulfilled if the conductors are of the same material, have the same cross-sectional area, are approximately the same length and have no branch circuits along the length, and either

   – the conductors in parallel are multi-core cables or twisted single-core cables or insulated conductors, or
   – the conductors in parallel are non-twisted single-core cables or insulated conductors in trefoil or flat formation and have a cross-sectional area less than or equal to 50 mm^2 in copper or 70 mm^2 in aluminium, or
   – if the conductors in parallel are non-twisted single-core cables or insulated conductors in trefoil or in flat formation and have a cross-sectional area greater than 50 mm^2 in copper or 70 mm^2 in aluminium, the special configuration necessary for such formations is adopted. These configurations consist of suitable groupings and spacings of the different phases or poles (*see* Annex Z).

or

b) special consideration shall be given to the load current sharing to meet the requirements of **5.2.6.1**.

This subclause does not preclude the use of ring final circuits either with or without spur connections.

Where adequate current sharing cannot be achieved or where four or more conductors have to be connected in parallel, consideration shall be given to the use of busbar trunking.

5.2.6.8 *Variation of installation conditions along a route*

Where the heat dissipation differs in one part of a route to another, the current-carrying capacity shall be determined so as to be appropriate for the part of the route having the most adverse conditions.

NOTE — This requirement can normally be neglected if heat dissipation only differs where the wiring is going through a wall of less than 0.35 m.

5.2.6.9 *Single-core cables with a metallic covering*

The metallic sheaths and/or non-magnetic armour of single-core cables in the same circuit shall be connected together at both ends of their run. Alternatively, to improve current-carrying capacity, the sheaths or armour of such cables having conductors of cross-sectional area exceeding 50 mm^2 and a non-conducting outer sheath may be connected together at one point in their run with suitable insulation at the unconnected ends, in which case the length of the cables from the connection point shall be limited so that voltages from sheaths and/or armour to earth:

a) do not cause corrosion when the cables are carrying their full load current, for example, by limiting the voltage to 25 V, and
b) do not cause danger or damage to property when the cables are carrying short-circuit current.

5.2.7 *Cross-sectional areas of conductors*

5.2.7.1 For mechanical reasons, the cross-sectional area of line conductors in a.c. circuits and of live conductors in d.c. circuits shall be not less than the values given in Table 9.

5.2.7.2 *Cross-sectional area of the neutral conductor*

In the absence of more precise information, the following shall apply.

5.2.7.2.1 The cross-sectional area of the neutral conductor, if any, shall be at least equal to the cross-sectional area of the line conductors:

a) in single-phase circuits with two conductors, whatever be the cross-sectional area of conductors;
b) in multi-phase circuits where the cross-sectional area of the line conductors is less than or equal to 16 mm^2 copper or 25 mm^2 aluminium;
c) in three-phase circuits likely to carry third harmonic currents and odd multiples of third harmonic currents and the total harmonic distortion is between 15 percent and 33 percent.

   NOTE — Such harmonic levels are to be met, for instance, in circuits feeding luminaires, including discharge lamps, such as fluorescent lighting.

5.2.7.2.2 Where the third harmonic and odd multiples of third harmonic currents is higher than 33 percent, total harmonic distortion, it may be necessary to increase the cross-sectional area of the neutral conductor (*see* **5.2.6.6.3** and Annex V).

NOTES

1 These levels occur for instance in circuits dedicated to IT applications.

Table 9 Minimum Nominal Cross-Sectional Area of Conductors
(*Clause* 5.2.7.1)

Sl No.	Type of Wiring System	Use of the Circuit	Conductor	
			Material	Minimum Permissible Nominal Cross Sectional Area mm^2
(1)	(2)	(3)	(4)	(5)
i)	Cables and insulated conductors	Lighting circuits	Cu	1.5
		Power circuits	Cu	2.5
			Al	10.0 (*see* Note 1)
		Signalling and control circuits	Cu	0.5 (*see* Note 2)
ii)	Bare Conductors	Power circuits	Cu Al	10 16
		Signalling and control circuits	Cu	4
iii)	Flexible connections with insulated conductors and cables	For a specific appliance	Cu	As specified in the relevant Indian Standard
		For any other application		0.5 (*see* Note 2)
		Extra low voltage circuits for special applications		0.5

NOTES
1 Connectors used to terminate aluminium conductors shall be tested and approved for this specific use.
2 In multi-core flexible cables containing 7 or more cores and in signalling control circuits intended for electronic equipment a minimum nominal cross sectional area of 0.1 mm is permitted.

a) For multi-core cables, the cross-sectional area of the line conductors is equal to the cross-sectional area of the neutral conductor, this cross-sectional area being chosen for the neutral to carry 1.45 × I_B of the line conductor.
b) For single-core cables, the cross-sectional area of the line conductors may be lower than the neutral cross-sectional area, the calculation being made :
– for the line: at I_B
– for the neutral: at a current equal to 1.45 I_B of the line.
2 *See* **4.4.4** for an explanation of I_B.

5.2.7.2.3 For polyphase circuits where the cross-sectional area of line conductors is greater than 16 mm^2 copper or 25 mm^2 aluminium, the cross-sectional area of the neutral conductor may be lower than the cross-sectional area of the line conductors if the following conditions are fulfilled simultaneously:

a) the load carried by the circuit in normal service is balanced between the phases and the third harmonic and odd multiples of third harmonics currents do not exceed 15 percent of the line conductor current;

NOTE — Usually, the reduced neutral cross-sectional area is not lower than 50 percent of the line conductor cross-sectional area.

b) the neutral conductor is protected against overcurrents according to **4.4.2.2**; and
c) the cross-sectional area of the neutral conductor is not less than 16 mm^2 copper or 25 mm^2 aluminium.

5.2.8 *Voltage Drop in Consumers' Installations*

In the absence of any other consideration, the voltage drop between the origin of the consumer's installation and the equipment should not be greater than that given in Table 47.

NOTE — Other considerations include start-up time for motors and equipment with high inrush current. Temporary conditions such as voltage transients and voltage variation due to abnormal operation may be disregarded.

5.2.9 *Electrical Connections*

5.2.9.1 Connections between conductors and between conductors and other equipment shall provide durable electrical continuity and adequate mechanical strength and protection.

NOTE — *See* IEC 61200-52.

5.2.9.2 The selection of the means of connection shall take account of, as appropriate:

a) the material of the conductor and its insulation;
b) the number and shape of the wires forming the conductor;
c) the cross-sectional area of the conductor; and
d) the number of conductors to be connected together.

NOTES
1 The use of soldered connections should be avoided, except in communication circuits. If used, the connections should be designed to take account of creep and mechanical stresses and temperature rise under fault conditions (*see* **5.2.5.6**, **5.2.5.7** and **5.2.5.8**).
2 Applicable standards include the IEC 60998 series, IEC 60947 (all Parts) and IEC 61535.
3 Terminals without the marking "r" (only rigid conductors), "f" (only flexible conductors), "s" or "sol"

(only solid conductors) are suitable for the connection of all types of conductors.

5.2.9.3 All connections shall be accessible for inspection, testing and maintenance, except for the following:

a) joints designed to be buried in the ground;
b) compound-filled or encapsulated joints;
c) connections between a cold tail and the heating element as in ceiling heating, floor heating and trace heating systems;
d) a joint made by welding, soldering, brazing or appropriate compression tool; and
e) joint forming part of the equipment complying with the appropriate product standard.

NOTE — A compound filled joint is, for example, a resin filled joint.

5.2.9.4 Where necessary, precautions shall be taken so that the temperature attained by connections in normal service shall not impair the effectiveness of the insulation of conductors connected to them or supporting them.

5.2.9.5 Conductor connections (not only final but also intermediate connections) shall only be made in suitable enclosures, for example, in connection boxes, outlet boxes, or in equipment if the manufacturer has provided space for this purpose. In this case, equipment shall be used where fixed connection devices are provided or provision has been made for the installation of connection devices. At the termination of final circuits conductors shall be terminated in an enclosure.

5.2.9.6 Connections and junction points of cables and conductors shall be relieved from mechanical stress. Strain relief devices shall be designed so as to avoid any mechanical damage to the cables or conductors.

5.2.9.7 Where a connection is made in an enclosure, the enclosure shall provide adequate mechanical protection and protection against relevant external influences.

5.2.9.8 *Connection of multi-wire, fine wire and very fine wire conductors*

5.2.9.8.1 In order to protect against the separation or spreading of individual wires of multi-wire, fine wire or very fine wire conductors, suitable terminals shall be used or the conductor ends shall be suitably treated.

5.2.9.8.2 Soldering of the whole conductor end of multi-wire, fine wire and very fine wire conductors is permitted if suitable terminals are used.

5.2.9.8.3 Soldered (tinned) conductor ends on fine wire and very fine wire conductors are not permissible at connection and junction points which are subject in service to a relative movement between the soldered and the non-soldered part of the conductor.

NOTE — Fine and very fine wire is in accordance with IEC 60228, Class 5 and Class 6.

5.2.9.9 Cores of sheathed cables from which the sheath has been removed and non-sheathed cables at the termination of conduit, ducting or trunking shall be enclosed as required by **5.2.9.5**.

5.2.10 *Selection and Erection of Wiring Systems to Minimize the Spread of Fire*

5.2.10.1 *Precautions within a fire-segregated compartment*

5.2.10.1.1 The risk of spread of fire shall be minimized by the selection of appropriate materials and erection in accordance with **5.2.10**.

5.2.10.1.2 Wiring systems shall be installed so that the general building structural performance and fire safety are not reduced.

5.2.10.1.3 Cables complying with, at least, the requirements of IEC 60332-1-2 and products classified as non-flame propagating may be installed without special precautions.

NOTE — In installations where a particular risk is identified, cables complying with the more onerous tests for bunched cables described in the IEC 60332-3 series may be necessary.

5.2.10.1.4 Cables not complying, as a minimum, with the resistance to the flame propagation requirements of IEC 60332-1-2 shall, if used, be limited to short lengths for connection of appliances to permanent wiring systems and shall, in any event, not pass from one fire-segregated compartment to another.

5.2.10.1.5 Products classified as non-flame propagating as specified in IS 8623 (Part 2), IEC 61537 and in the following series: IS 14297 (Part 1) and (Part 2/ Section 1), IS 14930 (Parts 1 & 2) and IEC 61534, may be installed without special precautions. Other products complying with standards having similar requirements for resistance to flame propagation may be installed without special precautions.

5.2.10.1.6 Parts of wiring systems other than cables not classified as non-flame propagating, as specified in IS 8623 (Part 2), IEC 60570, IEC 61537 and in the following series: IS 14297 (Part 1) and (Part 2/Section 1), IS 14930 (Parts 1 & 2) and IEC 61534, but which comply in all other respects with the requirements of their respective product standards shall, if used, be completely enclosed in suitable non-combustible building materials.

5.2.10.2 *Sealing of wiring system penetrations*

5.2.10.2.1 Where a wiring system passes through

elements of building construction such as floors, walls, roofs, ceilings, partitions or cavity barriers, the openings remaining after passage of the wiring system shall be sealed according to the degree of fire resistance (if any) prescribed for the respective element of building construction before penetration.

NOTES

1 During erection of a wiring system temporary sealing arrangements may be required.

2 During alteration work, sealing should be reinstated as quickly as possible.

5.2.10.2.2 Wiring systems which penetrate elements of building construction having specified fire resistance shall be internally sealed to the degree of fire resistance of the respective element before penetration as well as being externally sealed as required by **5.2.10.2.1**.

5.2.10.2.3 Conduit systems, cable trunking systems and cable ducting systems classified as non-flame propagating according to the relevant product standard and having a maximum internal cross-section area of 710 mm^2 need not be internally sealed provided that:

a) the system satisfies the test of IS/ IEC 60529 for IP33; and
b) any termination of the system in one of the compartments, separated by the building construction being penetrated, satisfies the test of IS/IEC 60529 for IP33.

5.2.10.2.4 No wiring system shall penetrate an element of building construction which is intended to be load bearing unless the integrity of the load bearing element can be assured after such penetration.

5.2.10.2.5 Sealing arrangements intended to satisfy **5.2.10.2.1** or **5.2.10.2.2** shall resist external influences to the same degree as the wiring system with which they are used, and in addition, they shall meet all of the following requirements:

a) they shall be resistant to the products of combustion to the same extent as the elements of building construction which have been penetrated;
b) they shall provide the same degree of protection from water penetration as that required for the building construction element in which they have been installed;
c) the seal and the wiring system shall be protected from dripping water which may travel along the wiring system or which may otherwise collect around the seal unless the materials used in the seal are all resistant to moisture when finally assembled for use.

NOTES

1 These requirements may be transferred to an IEC product standard, if such a standard is prepared.

a) They should be compatible with the materials of the wiring system with which they are in contact.

b) They should permit thermal movement of the wiring system without reduction of the sealing quality.

c) They should be of adequate mechanical stability to withstand the stresses which may arise through damage to the support of the wiring system due to fire.

2 The requirements of **5.2.10.2.5** may be satisfied if:

a) either cable cleats, cable ties or cable supports are installed within 750 mm of the seal and are able to withstand the mechanical loads expected following the collapse of the supports on the fire side of the seal to the extent that no strain is transferred to the seal; or

b) the design of the sealing system itself provides adequate support.

5.2.11 *Proximity of Wiring Systems to other Services*

5.2.11.1 *Proximity to electrical services*

Band I and band II voltage circuits according to IS 12360 (Part 2) shall not be contained in the same wiring system unless one of the following methods is adopted:

a) every cable or conductor is insulated for the highest voltage present; or
b) each conductor of a multicore cable is insulated for the highest voltage present in the cable; or
c) the cables are insulated for their system voltage and installed in a separate compartment of a cable ducting or cable trunking system; or
d) the cables are installed on a cable tray system where physical separation is provided by a partition; or
e) a separate conduit, trunking or ducting system is employed.

For SELV and PELV systems the requirements of **4.2.14** shall apply.

NOTES

1 Special considerations concerning electrical interference, both electromagnetic and electrostatic, may apply to telecommunication circuits, data transfer circuits and the like.

2 In the case of proximity of wiring systems and lightning protection systems, the IS/IEC 62305 series should be considered.

5.2.11.2 *Proximity of communications cables*

In the event of crossing or proximity of underground telecommunication cables and underground power cables, a minimum clearance of 100 mm shall be maintained, or the requirements according to (a) or (b) shall be fulfilled:

a) a fire-retardant partition shall be provided between the cables, for example, bricks, cable protecting caps (clay, concrete), shaped blocks

(concrete), or additional protection provided by cable conduit or troughs made of fire-retardant materials, or

b) for crossings, mechanical protection between the cables shall be provided, for example, cable conduit, concrete cable protecting caps or shaped blocks.

5.2.11.3 *Proximity to non-electrical services*

5.2.11.3.1 Wiring systems shall not be installed in the vicinity of services which produce heat, smoke or fumes likely to be detrimental to the wiring, unless it is suitably protected from harmful effects by shielding arranged so as not to affect the dissipation of heat from the wiring.

In areas not specifically designed for the installation of cables, for example, service shafts and cavities, the cables shall be laid so that they are not exposed to any harmful influence by the normal operation of the adjacent installations (for example, gas, water or steam lines).

5.2.11.3.2 Where a wiring system is routed below services liable to cause condensation (such as water, steam or gas services), precautions shall be taken to protect the wiring system from deleterious effects.

5.2.11.3.3 Where electrical services are to be installed in proximity to non-electrical services they shall be so arranged that any foreseeable operation carried out on the other services will not cause damage to the electrical services or the converse.

NOTE — This may be achieved by:
a) suitable spacing between the services; or
b) the use of mechanical or thermal shielding.

5.2.11.3.4 Where an electrical service is located in close proximity to non-electrical services, both the following conditions shall be met:

a) wiring systems shall be suitably protected against hazards likely to arise from the presence of the other services in normal use; and
b) fault protection shall be afforded in accordance with the requirements of **4.2.13**, non-electrical metallic services being considered as extraneous-conductive-parts.

5.2.11.3.5 No wiring system shall be run in a lift (or hoist) shaft unless it forms part of the lift installation.

5.2.12 *Selection and Erection of Wiring Systems in Relation to Maintainability, Including Cleaning*

5.2.12.1 With regard to maintainability, reference shall be made to **4.1.5.13**.

5.2.12.2 Where it is necessary to remove any protective measure in order to carry out maintenance, provision shall be made so that the protective measure can be reinstated without reduction of the degree of protection originally intended.

5.2.12.3 Provision shall be made for safe and adequate access to all parts of the wiring system which may require maintenance.

NOTE — In some situations, it may be necessary to provide permanent means of access by ladders, walkways, etc.

5.3 Selection and Erection of Electrical Equipment— Isolation, Switching and Control

5.3.1 *General and Common Requirements*

This standard shall provide compliance with the measures of protection for safety, the requirements for proper functioning for intended use of the installation, and the requirements appropriate to the external influences foreseen. Every item of equipment shall be selected and erected so as to allow compliance with the rules stated in the following clauses of this part and the relevant rules in other parts of this standard.

The requirements of this part are supplementary to the common rules given in **5.1**.

5.3.1.1 The moving contacts of all poles of multi-pole devices shall be so coupled mechanically that they make and break substantially together, except that contacts solely intended for the neutral may close before and open after the other contacts.

5.3.1.2 Except as provided in **5.3.7.3.2.7**, in multiphase circuits, single-pole devices shall not be inserted in the neutral conductor.

In single-phase circuits single-pole devices shall not be inserted in the neutral conductor, unless a residual current device complying with the rules of **4.2.13** is provided on the supply side.

5.3.1.3 Devices embodying more than one function shall comply with all the requirements of this part appropriate to each separate function.

5.3.2 *Devices for Protection against Indirect Contact by Automatic Disconnection of Supply*

5.3.2.1 *Overcurrent protective devices*

5.3.2.1.1 *TN systems*

In TN systems overcurrent protective devices shall be selected and erected according to the conditions specified in **4.4.5.2, 4.4.2** and in **5.3.4.3** for devices for protection against short-circuit, and shall satisfy the requirements of **4.2.11.3**.

5.3.2.1.2 *TT systems*

Under consideration.

5.3.2.1.3 *IT systems*

Where exposed conductive parts are interconnected, overcurrent protective devices for protection in the event of a second fault shall comply with **5.3.1.1** taking into account the requirements of **4.2.11.6**.

5.3.2.2 *Residual current protective devices*

5.3.2.2.1 *General conditions of installation*

Residual current protective devices in d.c. systems shall be specially designed for detection of d.c. residual currents, and to break circuit currents under normal conditions and fault conditions.

5.3.2.2.1.1 A residual current protective device shall ensure the disconnection of all live conductors in the circuit protected. In TN-S systems, the neutral need not be disconnected if the supply conditions are such that the neutral conductor can be considered to be reliably at earth potential.

NOTE —The conditions for verification that the neutral conductor is reliably at earth potential are under consideration.

5.3.2.2.1.2 No protective conductor shall pass through the magnetic circuit of a residual current protective device.

5.3.2.2.1.3 Residual current protective devices shall be so selected, and the electrical circuits so subdivided, that any earth-leakage current which may be expected to occur during normal operation of the connected load(s) will be unlikely to cause unnecessary tripping of the device.

NOTE — Residual current protective devices may operate at any value of residual current in excess of 50 percent of the rated operating current.

5.3.2.2.1.4 *Influence of d.c. components*

Under consideration.

5.3.2.2.1.5 The use of a residual current protective device associated with circuits not having a protective conductor, even if the rated operating residual current does not exceed 30 mA, shall not be considered as a measure sufficient for protection against indirect contact.

5.3.2.2.2 *Selection of devices according to their method of application*

5.3.2.2.2.1 Residual current protective devices may or may not have an auxiliary source, taking into account the requirements of **5.3.2.2.2.2**.

NOTE — The auxiliary source may be the supply system.

5.3.2.2.2.2 The use of residual current protective devices with an auxiliary source not operating automatically in the case of failure of the auxiliary source is permitted only if one of the two following conditions is fulfilled:

a) protection against indirect contact according to **4.2.13.1** is ensured even in the case of failure of the auxiliary supply; and
b) the devices are installed in installations operated, tested and inspected by instructed persons (BA4) or skilled persons (BA5).

5.3.2.2.3 *TN systems*

If for certain equipment or for certain parts of the installation, one or more of the conditions stated in **4.2.13.1.3** cannot be satisfied, those parts may be protected by a residual current protective device. In this case, exposed conductive parts need not be connected to the TN earthing system protective conductor, provided that they are connected to an earth electrode affording a resistance appropriate to the operating current of the residual current protective device. The circuit thus protected is to be treated as a TT system.

If, however, no separate earth electrode exists, connection of the exposed conductive parts to the protective conductor needs to be made on the source side of the residual current protective device.

5.3.2.2.4 *TT systems*

If an installation is protected by a single residual current protective device, this shall be placed at the origin of the installation, unless the part of the installation between the origin and the device complies with the requirement for protection by the use of class II equipment or equivalent insulation (*see* **4.2.13.2**).

NOTE — Where there is more than one origin, this requirement applies to each origin.

5.3.2.2.5 *IT systems*

Where protection is provided by a residual current protective device, and disconnection following a first fault is not envisaged, the residual non-operating current of the device shall be at least equal to the current which circulates on the first fault to earth of negligible impedance affecting a phase conductor.

5.3.2.3 *Insulation monitoring devices*

NOTE — Insulation monitoring devices may operate with an appropriate response time.

An insulation monitoring device provided is, a device continuously monitoring the insulation of an electrical installation. It is intended to indicate a significant reduction in the insulation level of the installation to allow the cause of this reduction to be found before the occurrence of a second fault, and thus avoid disconnection of the supply.

Accordingly, it is set at a value below that specified in **6.2.3.3** appropriate to the installation concerned.

Insulation monitoring devices shall be so designed or installed that it shall be possible to modify the setting only by the use of a key or a tool.

5.3.3 *Devices for Protection against Thermal Effects*

Under consideration.

NOTE — Pending this consideration, reference should be made to **705.422** of IEC 60364-7-705.

5.3.4 *Devices for Protection against Overcurrent*

5.3.4.1 *General requirements*

5.3.4.1.1 Fuse bases using screw-in fuses shall be connected so that the centre contact is on the supply side of the fuse base.

5.3.4.1.2 Fuse bases for plug-in fuse carriers shall be arranged so as to exclude the possibility of the fuse carrier making contact between conductive parts belonging to two adjacent fuse bases.

5.3.4.1.3 Fuses having fuse-links likely to be removed or placed by persons other than instructed (BA4) or skilled persons (BA5), shall be of a type which complies with the safety requirements of IEC 60269-3.

Fuses or combination units having fuse-links likely to be removed and replaced only by instructed persons (BA4) or skilled persons (BA5), shall be installed in such a manner that it is ensured that the fuse-links can be removed or placed without unintentional contact with live parts.

5.3.4.1.4 Where circuit-breakers may be operated by persons other than instructed persons (BA4) or skilled persons (BA5), they shall be so designed or installed that it shall not be possible to modify the setting of the calibration of their overcurrent releases without a deliberate act involving the use of a key or tool, and resulting in a visible indication of their setting or calibration.

5.3.4.2 *Selection of devices for protection of wiring systems against overloads*

The nominal current (or current setting) of the protective device shall be chosen in accordance with **4.4.4.1**.

NOTE — In certain cases, to avoid unintentional operation, the peak current values of the loads have to be taken into consideration. In the case of a cyclic load, the values of I_n and I_2 shall be chosen on the basis of values of I_B and I_z for the thermally equivalent constant load

where

I_B = the current for which the circuit is designed;

I_Z = the continuous current-carrying capacity of the cable;

I_n = the nominal current of the protective device; and

I_2 = the current ensuring effective operation of the protective device.

5.3.4.3 *Selection of devices for protection of wiring systems against short circuits*

The application of the rules of **4.4** for short-circuit duration up to 5 s shall take into account minimum and maximum short-circuit conditions.

Where the standard covering a protective device specifies both a rated service short-circuit breaking capacity, and a rated ultimate short-circuit breaking capacity, it is permissible to select the protective device on the basis of the ultimate short-circuit breaking capacity for the maximum short-circuit conditions. Operational circumstances may, however, make it desirable to select the protective device on the service short-circuit breaking capacity, for example, where a protective device is placed at the origin of the installation.

5.3.5 *Devices for Protection against Overvoltage*

5.3.5.1 *General*

This clause contains provisions for the application of voltage limitation to obtain an insulation coordination in the cases described in **4.5**, IS 15382 (Part 1), IEC 61312-2 and IEC 61643-12.

This clause gives the requirements for the selection and erection of:

a) surge protective devices (SPDs) for electrical installations of buildings to obtain a limitation of transient overvoltages of atmospheric origin transmitted via the supply distribution system and against switching overvoltages; and
b) SPDs for the protection against transient overvoltages caused by direct lightning strokes or lightning strokes in the vicinity of buildings, protected by a lightning protection system.

This clause does not take into account surge protective components which may be incorporated in the appliances connected to the installation. The presence of such components may modify the behaviour of the main surge protective device of the installation and may need an additional coordination.

This clause applies to a.c. power circuits. For d.c. power circuits, the requirements in this clause may be applied as far as is useful. For special applications, other or additional requirements may be necessary in IEC 60364-7.

5.3.5.2 *Selection and erection of SPDs in building installations*

5.3.5.2.1 *Use of SPDs*

The protection against overvoltages of atmospheric origin (caused by indirect, distant lightning strokes) and switching overvoltages are included in **4.5.3**. This

protection is normally provided by the installation of test class II SPDs and if necessary test class III SPDs.

When required in accordance with **4.5** or otherwise specified, SPDs shall be installed near the origin of the installation or in the main distribution assembly, closest to the origin of the installation inside the building.

The protection against the effects of direct lightning strokes or strokes near to the supply system are included in IEC 61312-1 which, also describes the correct selection and application of SPDs according to the Lightning Protection Zones (LPZ) concept. The LPZ concept describes the installation of test class I, test class II and test class III SPDs.

When required in accordance with IEC 61312-1 or otherwise specified, SPDs shall be installed at the origin of the installation.

Additional SPDs may be necessary to protect sensitive equipment. Such SPDs shall be coordinated with the SPDs installed upstream (*see* **5.3.5.2.3.6**).

In the case where SPDs are part of the fixed electrical installation, but not mounted inside a distribution board (for example, in a socket outlet), their presence shall be indicated by a label on or as near as is reasonably possible to the origin of the circuit under consideration.

5.3.5.2.2 *Connection of SPDs*

Surge protective devices at or near the origin of the installation shall be connected at least between the following points (*see* Annexure AA, BB and CC):

a) if there is a direct connection between the neutral conductor and the PE at or near the origin of the installation or if there is no neutral conductor:

   — between each line conductor and either the main earthing terminal or the main protective conductor, whichever is the shortest route;

   NOTE — The impedance connecting the neutral to the PE in IT systems is not considered as a connection.

b) if there is no direct connection between the neutral conductor and the PE at or near the origin of the installation, then either

   — between each line conductor and either the main earthing terminal or the main protective conductor, and between the neutral conductor and either the main earthing terminal or the protective conductor, whichever is the shortest route –connection type 1;

   or

   — between each line conductor and the neutral conductor and between the neutral conductor and either the main earthing terminal or the protective conductor, whichever route is shorter – connection type 2.

   NOTE — If a line conductor is earthed, it is considered to be equivalent to a neutral conductor for the application of this subclause.

SPDs at or near the origin of the installation are, in general, installed as shown in Annexes AA, BB and CC and according to Table 10.

5.3.5.2.3 *Selection of surge protective devices* (*SPDs)*

The SPDs shall comply with IEC 61643-1. Additional information regarding selection and application is given in IEC 61643-12.

5.3.5.2.3.1 *Selection with regard to protection level* (U_p)

The protection level U_p of SPDs shall be selected in accordance with impulse withstand voltage category II of Table 6 (*see also* **4.5**).

If IEC 61312-1 requires SPDs for the protection against overvoltages caused by direct lightning strokes, the protection level of these SPDs shall also be selected in accordance with impulse withstand voltage category II of Table 6 (*see* **4.4**).

For example in 230/400 V installations, the protection level U_p shall not exceed 2.5 kV.

When connection type 2 according to **5.3.5.2.2** is used, the above requirements also apply to the total protection level between line conductors and PE.

When the required protection level cannot be reached with a single set of SPDs, additional, coordinated SPDs shall be applied to ensure the required protection level.

5.3.5.2.3.2 *Selection with regard to continuous operating voltage* (U_c)

The maximum continuous operating voltage U_c of SPDs shall be equal to or higher than shown in the following Table 11.

5.3.5.2.3.3 *Selection with regard to temporary overvoltages* (*TOVs)*

The SPDs selected according to **5.3.5.2.3** shall withstand the temporary overvoltages due to faults within low-voltage systems (*see* **4.5.2**).

This is confirmed by the selection of SPDs which comply with the relevant test requirements of **7.7.6** of IS/IEC 61643-1.

To fail safely in case of TOVs due to earth faults within the high-voltage system (*see* **4.5.2**), the SPDs connected to the PE shall pass the test of **7.7.4** of IS/IEC 61643-1.

Table 10 Connection of Surge Protective Devices Dependent on System Configuration
(*Clause* 5.3.5.2.2)

SPDs Connected Between	System Configuration at the Installation Point of SPD							
	TT		TN-C	TN-S		IT with distributed neutral		IT without distributed neutral
	Installation according to			Installation according to		Installation according to		
	Connection Type 1	Connection Type 2		Connection Type 1	Connection Type 2	Connection Type 1	Connection Type 2	
Each line conductor and neutral conductor	+	.	NA	+	.	+	.	NA
Each line conductor and PE conductor	.	NA	NA	.	NA	.	NA	.
Neutral conductor and PE conductor	.	.	NA	.	.	.	.	NA
Each line conductor and PEN conductor	NA	NA	.	NA	NA	NA	NA	NA
Line conductors	+	+	+	+	+	+	+	+

.— mandatory
NA — not applicable
\+ — optional, in addition

Table 11 Minimum Required U_c of the SPD Dependent on Supply System Configuration
(*Clause* 5.3.5.2.3.2)

SPDs Connected Between	System Configuration of Distribution Network				
	TT	TN-C	TN-S	IT with distributed neutral	IT without distributed neutral
Line conductor and neutral conductor	1.1 U_o	NA	1.1U_o	1.1 U_o	NA
Each line conductor and PE conductor	1.1 U_o	NA	1.1 U_o	$\sqrt{3}U_o$ [1)]	Line-to-line voltage[1)]
Neutral conductor and PE conductor	U_o [1)]	NA	U_o [1)]	U_o [1)]	NA
Each line conductor and PEN conductor	NA	1.1 U_o	NA	NA	NA

NA — not applicable
NOTES
1 U_o is the line-to-neutral voltage of the low-voltage system.
2 This table is based on IEC 61643-1 amendment 1.

[1)] These values are related to worst case fault conditions, therefore the tolerance of 10 percent is not taken into account.

In addition, SPDs installed in location 4a according to Fig. 89 shall withstand such TOVs as defined in test of **7.7.4** of IS/IEC 61643-1.

NOTES

1 Appropriate pass criteria are under consideration to define the meaning of withstand.

2 The loss of neutral is not covered by these requirements. Though there is currently no specific test in IS/IEC 61643-1, SPDs are expected to fail safely.

5.3.5.2.3.4 *Selection with regard to discharge current* (I_n) *and impulse current* (I_{imp})

If **4.5.3** requires SPDs, the nominal discharge current I_n shall not be less than 5 kA 8/20 for each mode of protection.

In case of installation according to **5.3.5.2.2** connection type 2, the nominal discharge current I_n for the surge protective device connected between the neutral conductor and the PE shall not be less than 20 kA 8/20 for three-phase systems and 10 kA 8/20 for single-phase systems.

If IEC 61312-1 requires SPDs, the lightning impulse current I_{imp} according to IEC 61643-1 shall be calculated according to IEC 61312-1. Further information is given in IEC 61643-12. If the current value cannot be established, the value of I_{imp} shall not be less than 12.5 kA for each mode of protection.

In case of an installation according to **5.3.5.2.2** connection type 2, the lightning impulse current I_{imp} for the surge protective device connected between the neutral conductor and the PE shall be calculated similarly to the above mentioned standards. If the current value cannot be established the value of I_{imp} shall not be less than 50 kA for three-phase systems and 25 kA for single-phase systems.

When a single SPD is used for protection according to both **7.7.4** and IEC 61312-1, the rating of I_n and of I_{imp}

shall be in agreement with the above values.

5.3.5.2.3.5 *Selection with regard to the expected short-circuit current*

The short-circuit withstand of the SPDs (in case of SPD failure) together with the specified associated (internal or external) overcurrent protective device shall be equal to or higher than the maximum short-circuit current expected at the point of installation taking into account the maximum overcurrent protective devices specified by the SPD manufacturer.

In addition, when a follow current interrupting rating is declared by the manufacturer, it shall be equal to or higher than the expected short-circuit current at the point of installation.

SPDs connected between the neutral conductor and the PE in TT- or TN-systems, which allow a power frequency follow-up current after operation (for example, spark gaps) shall have a follow current interrupting rating greater or equal to 100 A.

In IT systems, the follow current interrupting rating for SPDs connected between the neutral conductor and the PE shall be the same as for SPDs connected between phase and neutral.

5.3.5.2.3.6 *Co-ordination of SPDs*

According to IEC 61312-3 and IEC 61643-12, considerations shall be taken regarding the necessary co-ordination of SPDs in the installation. The SPD manufacturers shall provide sufficient information in their documentation about the way to achieve coordination between SPDs.

5.3.5.2.4 *Protection against overcurrent and consequences of an SPD failure*

Protection against SPD's short-circuits is provided by the overcurrent protective devices F2 (*see* figures in Annexure AA, BB, CC and DD) which are to be selected according to the maximum recommended rating for the overcurrent protective device given in the manufacturer's SPD instructions.

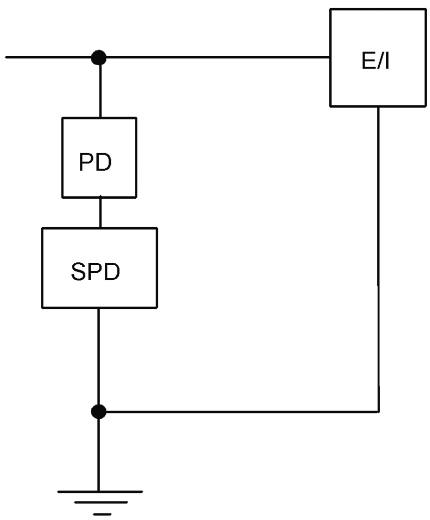
If the overcurrent protective devices F1 (which are part of the installation, *see* figures in Annexure AA, BB, CC and DD) have a rating smaller than or equal to the maximum recommended rating for the overcurrent protective devices F2, then F2 can be omitted.

The cross-sectional area of conductors connecting the overcurrent protective devices to the line conductors shall be rated according to the maximum possible short-circuit current (F1, F2 and F3 are shown in Annexure AA, BB, CC and DD).

Depending on the location of protective devices used to disconnect the SPD in case of SPD failure, priority may be given either to the continuity of supply or to the continuity of protection.

In all cases, the discrimination between protective devices shall be ensured.

- If protective devices are installed in the surge protective device circuit, the continuity of the supply is ensured, but neither the installation nor the equipment is protected against possible further overvoltages (*see* Fig. 56). These protective devices may be internal disconnectors.
- If protective devices are inserted in the installation upstream of the circuit where SPDs are installed, the failure of the surge protective device may cause interruption of supply: the circuit interruption will last until the surge protective device is replaced (*see* Fig. 57).



PD — protective device of the SPD

SPD— surge protective device

E/I — equipment or installation to be protected against overvoltages

FIG. 56 PRIORITY TO THE CONTINUITY OF SUPPLY

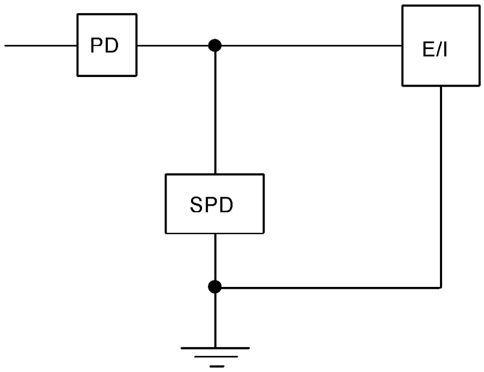


FIG. 57 PRIORITY TO THE CONTINUITY OF PROTECTION

In order to increase the reliability and the probability of having at the same time continuity of supply and continuity of protection, it is permitted to use the scheme described in Fig. 58.

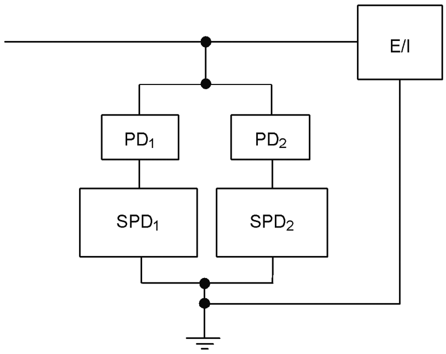


FIG. 58 COMBINATION OF CONTINUITY OF SUPPLY AND CONTINUITY OF PROTECTION

In this case, two identical *SPDs* (SPD_1 and SPD_2) are connected to two identical protective devices (PD_1 and PD_2). The failure mode of one of the SPDs (for example, SPD_1) will not influence the effectiveness of the second SPD (for example, SPD_2) and will lead to the operation of its own protective device (for example, PD_1). Such an arrangement will significantly increase the probability of having continuity of supply and continuity of protection.

5.3.5.2.5 *Protection against indirect contact*

Protection against indirect contact, as defined in **4.2**, shall remain effective in the protected installation even in case of failures of SPDs.

In case of automatic disconnection of supply:

a) in TN systems this may, in general, be fulfilled by the overcurrent device on the supply side of the surge protective device;
b) in TT systems this may be fulfilled by either,
   1) the installation of SPDs on the load side of an RCD (*see*Fig. 90), or
   2) the installation of SPDs on the supply side of an RCD. Because of the possibility of the failure of an SPD between N and PE conductors,
      - the conditions of **4.2.11.5.1** shall be met, and
      - the SPD shall be installed in accordance with **5.3.5.2.2** connection type 2.
c) in IT systems, no additional measure is needed.

5.3.5 2.6 *SPD installation in conjunction with RCDs*

If SPDs are installed in accordance with **5.3.5.2.1** and are on the load side of a residual current device, an RCD with or without time delay, but having an immunity to surge currents of at least 3 kA 8/20 shall be used.

NOTES

1 S-type RCDs in accordance with IS 12640 (Part 1) and IS 12640 (Part 2) satisfy this requirement.

2 In the case of surge current higher than 3 kA 8/20, the RCD may trip causing interruption of the power supply.

5.3.5.2.7 *Measurement of the insulation resistance*

During the measurement of the insulation resistance of the installation according to **6**, SPDs installed at or near the origin of the installation or in a distribution board and not rated for the test voltage of the insulation measurement may be disconnected.

In the case where SPDs connected to the PE conductor are part of a socket outlet, they shall withstand the test voltage for measuring the insulation resistance according to **6**.

5.3.5.2.8 *SPD status indication*

Indication that the SPD no longer provides overvoltage protection shall be provided,

a) either by an SPD status indicator, and
b) or by a separate SPD protective device such as addressed in **5.3.5.2.4**.

5.3.5.2.9 *Connecting conductors*

Connecting conductors are the conductors from the line conductor to the surge protective device and from the surge protective device to the main earthing terminal or to the protective conductor.

Because increasing the length of the connecting conductors of SPDs reduces the effectiveness of overvoltage protection, optimum overvoltage protection is achieved when all connecting conductors of SPDs are as short as possible (preferably not exceeding 0.5 m for the total lead length) and without any loops (*see* Fig. 59). If distance $a + b$ (*see* Fig. 59) cannot be reduced below 0.5 m, the scheme in Fig. 60 may be adopted.

5.3.5.2.10 *Cross-section of earthing conductors*

The earthing conductors of SPDs at or near the origin of the installation shall have a minimum cross-sectional area of 4 mm² copper or equivalent.

When there is a lightning protection system, a minimum cross-sectional area of 16 mm² copper or equivalent is necessary for SPDs tested in accordance with test class I of IS/IEC 61643-1.

5.3.6 *Co-ordination of various Protective Devices*

5.3.6.1 *Discrimination between overcurrent protective devices*

Under consideration.

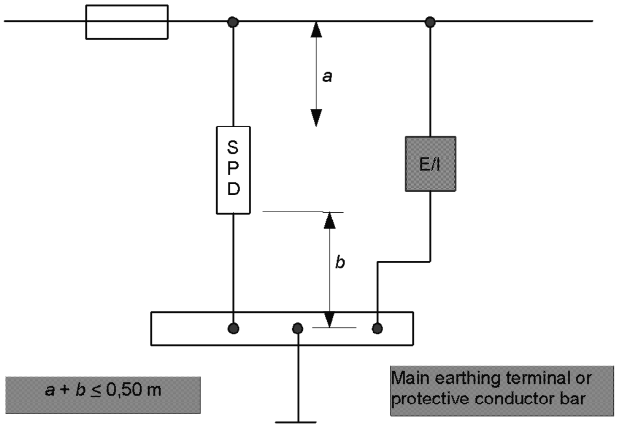


FIG. 59 EXAMPLE OF INSTALLATION OF SPDS AT OR NEAR THE ORIGIN OF THE INSTALLATION

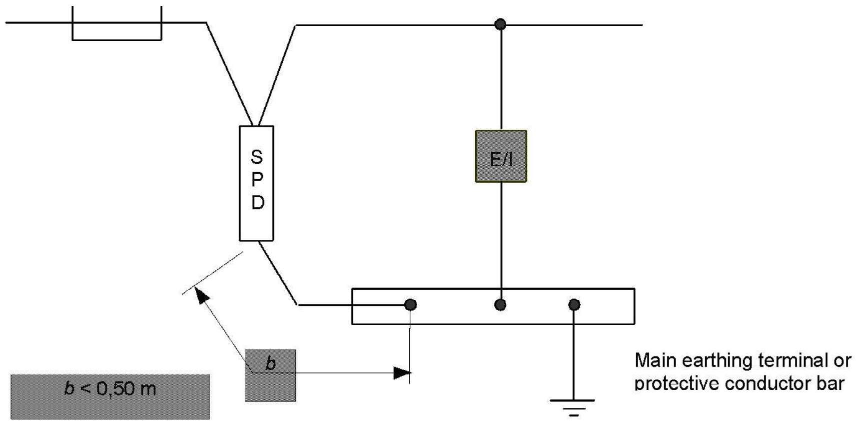


FIG. 60 EXAMPLE OF INSTALLATION OF SPDS AT OR NEAR THE ORIGIN OF THE INSTALLATION

5.3.6.2 *Association of residual current protective devices with overcurrent protective devices*

5.3.6.2.1 Where a residual current protective device is incorporated or combined with a device for overcurrent protection, the characteristics of the assembly of protective devices (breaking capacity, operating characteristics in relation to rated current) shall satisfy the rules of **4.4.4, 4.4.5, 5.3.4.2** and **5.3.4.3**.

5.3.6.2.2 Where a residual current protective device is neither incorporated in, nor combined with, a device for overcurrent protection:

a) overcurrent protection shall be ensured by appropriate protective devices according to the rules of **4.4**;
b) the residual current protective device shall be able to withstand without damage the thermal and mechanical stresses to which it is likely to be subjected in the event of a short-circuit occurring on the load side of the location where it is installed; and
c) the residual current protective device shall not be damaged under these short-circuit conditions even when, due to unbalanced current or to current flowing to earth, the residual current protective device itself tends to open.

NOTE — The stresses mentioned depend on the prospective short-circuit current at the point where the residual current prospective device is installed, and the operating characteristics of the device providing short-circuit protection.

5.3.6.3 *Discrimination between residual current protective devices*

Discrimination between residual current protective devices installed in series may be required for service reasons, particularly when safety is involved, to provide continuity of supply to the parts of the installation not involved in the fault, if any.

This discrimination can be achieved by selecting and erecting residual current protective devices which, while ensuring the required protection to the different parts of the installation, disconnect from the supply only that part of the installation that is located on the load side of the residual current protective device installed

on the supply side of the fault, and closest to it.

To ensure discrimination between two residual current protective devices in series, these devices shall satisfy both the following conditions:

a) the non-actuating time-current characteristic of the residual current protective device located on the supply side (upstream) shall lie above the total operating time-current characteristic of the residual current protective device located on the load side (downstream), and
b) the rated residual operating current on the device located on the supply side shall be higher than that of the residual current protective device located on the load side.

In the case of residual current protective devices complying with the requirements of IS 12640 (Part 1) and IS 12640 (Part 2), the rated residual operating current of the device located on the supply side shall be at least three times that of the residual current protective device located on the load side.

5.3.7 *Isolation and Switching*

5.3.7.1 *Introduction*

This clause deals with non-automatic local and remote isolation and switching measures which prevent or remove dangers associated with electrical installations or electrically powered equipment and machines.

5.3.7.2 *General*

5.3.7.2.1 According to the intended function(s), every device provided for isolation or switching shall comply with the relevant requirements of this part.

5.3.7.2.2 In TN-C systems, the PEN conductor shall not be isolated or switched. In TN-S systems, the neutral conductor need not be isolated or switched.

NOTE — Protective conductors in all systems are required not to be isolated or switched (*see also* **5.4.3.3.3**).

5.3.7.2.3 The measures described in this part are not alternatives to the protective measures described in **4.2** to **4.5**, inclusive.

5.3.7.3 *Isolation*

5.3.7.3.1 *General*

5.3.7.3.1.1 Every circuit shall be capable of being isolated from each of the live supply conductors, except as detailed in **5.3.7.2.2**.

Provisions may be made for isolation of a group of circuits by a common means, if the service conditions allow this.

5.3.7.3.1.2 Suitable means shall be provided to prevent any equipment from being unintentionally energized.

NOTE — Such precautions may include one or more of the following measures:
a) padlocking;
b) warning notices; and
c) location within a lockable space or enclosure.

Short-circuiting and earthing may be used as a supplementary measure.

5.3.7.3.1.3 Where an item of equipment or enclosure contains live parts connected to more than one supply, a warning notice shall be placed in such a position that any person gaining access to live parts will be warned of the need to isolate those parts from the various supplies unless an interlocking arrangement is provided to ensure that all the circuits concerned are isolated.

5.3.7.3.1.4 Where necessary, suitable means shall be provided for the discharge of stored electrical energy (*see* **5.5**).

5.3.7.3.2 *Devices for isolation*

5.3.7.3.2.1 The devices for isolation shall effectively isolate all live supply conductors from the circuit concerned, subject to the provisions of **5.3.7.2.2**.

Equipment used for isolation shall comply with **5.3.7.3.2.2** to **5.3.7.3.2.8**.

5.3.7.3.2.2 Devices for isolation shall comply with the following two conditions:

a) withstand in the new, clean and dry condition, when in the open position, across the terminals of each pole, the impulse voltage value given in Table 12 in relation to the nominal voltage of the installation.

   NOTE — Greater distances than those corresponding to the impulse-withstand voltages may be necessary from consideration of aspects other than isolation.

b) have a leakage current across open poles not exceeding:
   – 0.5 mA per pole in the new, clean and dry condition, and
   – 6 mA per pole at the end of the conventional service life of the device as determined in the relevant standard,

   when tested, across the terminals of each pole, with a voltage value equal to 110 percent of the phase to neutral value corresponding to the nominal voltage of the installation. In the case of d.c. testing, the value of the d.c. voltage shall be the same as the r.m.s. value of the a.c. test voltage.

5.3.7.3.2.3 The isolating distance between open contacts of the device shall be visible or be clearly and reliably indicated by “off” or “open” marking. Such

Table 12 Impulse-withstand Voltage as a Function of the Nominal Voltage
(*Clause* 5.3.7.3.2.2)

Nominal Voltage of the Installation[1)]		Impulse-withstand Voltage for Isolating Devices kV	
Three-Phase Systems V	Single-Phase Systems with Middle Point V	Overvoltage Category III	Overvoltage Category IV
230/400, 277/480, 00/690, 577/1 000	120 – 240	3 5 8	5 8 10

[1)] According to IS 12360.

NOTES

1 As regards transient atmospheric overvoltages no distinction is made between earthed and unearthed systems.

2 The impulse withstand voltages are referred to an altitude of 2 000 m.

indication shall only occur when the isolating distance between open contacts on each pole of the device has been attained.

NOTE — The marking required by this subclause may be achieved by the use of the symbols "O" and "I" to indicate the open and closed positions respectively.

5.3.7.3.2.4 Semiconductor devices shall not be used as isolating devices.

5.3.7.3.2.5 Devices for isolation shall be designed and/ or installed so as to prevent unintentional closure.

NOTE — Such closure might be caused, for example, by shocks and vibrations.

5.3.7.3.2.6 Provision shall be made for securing off-load isolating devices against inadvertent and unauthorized opening.

NOTE — This may be achieved by locating the device in a lockable space or enclosure or by padlocking. Alternatively, the off-load device may be interlocked with a load-breaking one.

5.3.7.3.2.7 Means of isolation shall preferably be provided by a multipole switching device which disconnects all poles of the relevant supply but single-pole devices situated adjacent to each other are not excluded.

NOTE — Isolation may be achieved, for example, by the following means:

a) disconnectors (isolators), switch-disconnectors, multipole or single-pole;
b) plugs and socket outlets;
c) fuse-links;
d) fuses; and
e) special terminals which do not require the removal of a wire.

5.3.7.3.2.8 All devices used for isolation shall be clearly identified, for example by marking, to indicate the circuit which they isolate.

5.3.7.4 *Switching-off for mechanical maintenance*

5.3.7.4.1 *General*

5.3.7.4.1.1 Means of switching-off shall be provided where mechanical maintenance may involve a risk of physical injury.

NOTES

1 Electrically powered mechanical equipment may include rotating machines as well as heating elements and electromagnetic equipment for electrical installations of machines).

2 Examples of installations where means for switching-off for mechanical maintenance are used:

a) cranes,
b) lifts,
c) escalators,
d) conveyors,
e) machine-tools, and
f) pumps.

3 Systems powered by other means, for example, pneumatic, hydraulic or steam, are not covered by these rules. In such cases, switching-off any associated supply of electricity may not be a sufficient measure.

5.3.7.4.1.2 Suitable means shall be provided to prevent electrically powered equipment from becoming unintentionally reactivated during mechanical maintenance, unless the means of switching-off is continuously under the control of any person performing such maintenance.

NOTE — Such means may include one or more of the following measures:

a) padlocking;
b) warning notices; and
c) location within a lockable space or enclosure.

5.3.7.4.2 *Devices for switching-off for mechanical maintenance*

5.3.7.4.2.1 Devices for switching-off for mechanical

maintenance shall be inserted preferably in the main supply circuit.

Where for this purpose switches are provided, they shall be capable of cutting off the full-load current of the relevant part of the installation. They need not necessarily interrupt all live conductors.

Interruption of a control circuit of a drive or the like is permitted only where,

- supplementary safeguards, such as mechanical restrainers, or
- requirements of an IS specification for the control devices used

provide a condition equivalent to the direct interruption of the main supply.

NOTE — Switching-off for mechanical maintenance may be achieved, for example, by means of:

a) multipole switches;
b) circuit breakers;
c) control switches operating contactors; and
d) plugs and sockets.

5.3.7.4.2.2 Devices for switching-off for mechanical maintenance or control switches for such devices shall require manual operation.

The clearance between open contacts of the device shall be visible or be clearly and reliably indicated by "off" or "open" marking. Such indication shall only occur when the "off" or "open" position on each pole of the device has been attained.

NOTE — The marking required by this subclause may be achieved by the use of the symbols "O" and "I" to indicate the open and closed positions respectively.

5.3.7.4.2.3 Devices for switching-off for mechanical maintenance shall be designed and/or installed so as to prevent unintentional switching on.

NOTE — Such switching on might be caused for example by shocks and vibrations.

5.3.7.4.2.4 Devices for switching-off for mechanical maintenance shall be placed and marked so as to be readily identifiable and convenient for their intended use.

5.3.7.5 *Emergency switching*

5.3.7.5.1 *General*

NOTE — Emergency switching may be emergency switching-on or emergency switching-off.

5.3.7.5.1.1 Means shall be provided for emergency switching of any part of an installation where it may be necessary to control the supply to remove an unexpected danger.

NOTE — Examples of installations where means for emergency switching (apart from emergency stopping in accordance with **5.3.7.5.1.5**) are used:

a) pumping facilities for flammable liquids;
b) ventilation systems;
c) large computers;
d) discharge lighting with high-voltage supply, for example, neon signs;
e) certain large buildings, for example department stores;
f) electrical testing and research facilities;
g) teaching laboratories;
h) boiler-rooms;
j) large kitchens.

5.3.7.5.1.2 Where a risk of electric shock is involved, the emergency switching device shall cut off all live conductors except as provided in **5.3.7.2.2**.

5.3.7.5.1.3 Means for emergency switching, including emergency stopping, shall act as directly as possible on the appropriate supply conductors.

The arrangement shall be such that one single action only will cut off the appropriate supply.

5.3.7.5.1.4 The arrangement of the emergency switching shall be such that its operation does not introduce a further danger or interfere with the complete operation necessary to remove the danger.

NOTES

1 Where this switching includes the function of emergency, in the case of machines, the relevant requirements are **5.3.7.5.1.5**.Means of emergency stopping shall be provided where electrically produced movements may give rise to danger.

2 Examples of installations where means for emergency stopping are used:

a) escalators;
b) lifts;
c) elevators;
d) conveyors;
e) electrically driven doors;
f) machine-tools; and
g) car-washing plants.

5.3.7.5.1.5 Means of emergency stopping shall be provided where electrically produced movements may give rise to danger.

NOTE — Examples of installations where means for emergency stopping are used:

a) escalators;
b) lifts;
c) elevators;
d) conveyors;
e) electrically driven doors;
f) machine-tools; and
g) car-washing plants.

5.3.7.5.4.2 *Devices for emergency switching*

5.3.7.5.4.2.1 The devices for emergency switching shall be capable of breaking the full-load current of the relevant parts of the installation taking account of stalled motor currents where appropriate.

5.3.7.5.4.2.2 Means for emergency switching may consist of

a) one switching device capable of directly cutting off the appropriate supply, or
b) a combination of equipment activated by a single action for the purpose of cutting off the appropriate supply.

For emergency stopping, retention of the supply may be necessary, for example, for braking of moving parts.

NOTE — Emergency switching may be achieved, for example, by means of:

a) switches in the main circuit, and
b) push-buttons and the like in the control (auxiliary) circuit.

5.3.7.5.4.2.3 Hand-operated switching devices for direct interruption of the main circuit shall be selected where practicable.

Circuit-breakers, contactors, etc, operated by remote control shall open on de-energization of coils, or other equivalent failure-to-safety techniques shall be employed.

5.3.7.5.4.2.4 The means of operating (handles, push-buttons, etc) devices for emergency switching shall be clearly identified, preferably coloured red with a contrasting background.

5.3.7.5.4.2.5 The means of operating shall be readily accessible at places where a danger might occur and, where appropriate, at any additional remote position from which that danger can be removed.

5.3.7.5.4.2.6 The means of operation of a device for emergency switching shall be capable of latching or being restrained in the "off" or "stop" position, unless both the means of operation for emergency switching and for re-energizing are under the control of the same person.

The release of an emergency switching device shall not re-energize the relevant part of the installation.

5.3.7.5.4.2.7 Devices for emergency switching, including emergency stopping, shall be so placed and marked as to be readily identifiable and convenient for their intended use.

5.3.7.6 *Functional switching* (*control*)

5.3.7.6.1 *General*

5.3.7.6.1.1 A functional switching device shall be provided for each part of a circuit which may require to be controlled independently of other parts of the installation.

5.3.7.6.1.2 Functional switching devices need not necessarily control all live conductors of a circuit.

A single-pole switching device shall not be placed in the neutral conductor.

5.3.7.6.1.3 In general, all current-using apparatus requiring control shall be controlled by an appropriate functional switching device.

A single-functional switching device may control several items of apparatus intended to operate simultaneously.

5.3.7.6.1.4 Plugs and socket-outlets rated at not more than 16 A may be used for functional switching.

5.3.7.6.1.5 Functional switching devices ensuring the change-over of supply from alternative sources shall affect all live conductors and shall not be capable of putting the sources in parallel, unless the installation is specifically designed for this condition.

In these cases, no provision is to be made for isolation of the PEN or protective conductors.

5.3.7.6.2 *Functional switching devices*

5.3.7.6.2.1 Functional switching devices shall be suitable for the most onerous duty they may be called upon to perform.

5.3.7.6.2.2 Functional switching devices may control the current without necessarily opening the corresponding poles.

NOTES

1 Semiconductor switching devices are examples of devices capable of interrupting the current in the circuit but not opening the corresponding poles.

2 Functional switching may be achieved, for example by means of

a) switches;
b) semiconductor devices;
c) circuit-breakers;
d) contactors;
e) relays; and
f) plugs and socket-outlets up to 16 A.

5.3.7.6.2.3 Disconnectors, fuses and links shall not be used for functional switching.

5.3.7.6.3 *Control circuits* (*auxiliary circuits*)

Control circuits shall be designed, arranged and protected to limit dangers resulting from a fault between the control circuit and other conductive parts liable to cause malfunction (for example, inadvertent operations) of the controlled apparatus.

5.3.7.6.4 *Motor control*

5.3.7.6.4.1 Motor control circuits shall be designed so as to prevent any motor from restarting automatically after a stoppage due to a fall in or loss of voltage, if such starting is liable to cause danger.

5.3.7.6.4.2 Where reverse-current braking of a motor is provided, provision shall be made for the avoidance

of reversal of the direction of rotation at the end of braking if such reversal may cause danger.

5.3.7.6.4.3 Where safety depends on the direction of rotation of a motor, provision shall be made for the prevention of reverse operation due to, for example, a reversal of phases.

NOTE — Attention is called to danger which may arise from the loss of one phase.

5.4 Selection and Erection of Electrical Equipment —Earthing Arrangements and Protective Conductors

5.4.1 *Void*

5.4.2 *Earthing Arrangements*

5.4.2.1 *General requirements*

5.4.2.1.1 The earthing arrangements may be used jointly or separately for protective and functional purposes according to the requirements of the electrical installation. The requirements for protective purposes shall always take precedence.

5.4.2.1.2 Where provided, earth electrodes within an installation shall be connected to the main earthing terminal using an earthing conductor.

NOTE — An installation does not need to have its own earth electrode.

5.4.2.1.3 Where the supply to an installation is at high voltage, requirements concerning the earthing arrangements of the high voltage supply and of the low-voltage installation shall also comply with **4.5.2**.

5.4.2.1.4 The requirements for earthing arrangements are intended to provide a connection to earth which:

a) is reliable and suitable for the protective requirements of the installation;
b) can carry earth fault currents and protective conductor currents to earth without danger from thermal, thermo-mechanical and electromechanical stresses and from electric shock arising from these currents;
c) if relevant, is also suitable for functional requirements;
d) is suitable for the foreseeable external influences (*see* **5.1**), for example, mechanical stresses and corrosion.

5.4.2.1.5 Consideration shall be given to the earthing arrangements where currents with high frequencies are expected to flow (*see* **4.5.4**).

5.4.2.1.6 Protection against electric shock, as stated in **4.2**, shall not be adversely affected by any foreseeable change of the earth electrode resistance (for example, due to corrosion, drying or freezing).

5.4.2.2 *Earth electrodes*

5.4.2.2.1 The type, materials and dimensions of earth electrodes shall be selected to withstand corrosion and to have adequate mechanical strength for the intended lifetime (*see* IS 3043).

NOTES

1 For corrosion, the following parameters may be considered: the soil *pH* at the site, soil resistivity, soil moisture, stray and leakage a.c. and d.c. current, chemical contamination, and proximity of dissimilar materials. For materials commonly used for earth electrodes, the minimum sizes, from the point of view of corrosion and mechanical strength, when embedded in the soil or in concrete, shall be as specified in IS 3043.

2 The minimum thickness of protective coating is greater for vertical earth electrodes than for horizontal earth electrodes because of their greater exposure to mechanical stresses while being embedded.

If a lightning protection system is required, **5.4** of IS/IEC 62305-3 applies.

5.4.2.2.2 The earthing arrangement shall not rely on a metallic pipe for flammable liquids or gases as the earth electrode and their buried length shall not be considered when dimensioning the earth electrode.

NOTE —This requirement does not preclude the protective equipotential bonding via the main earthing terminal (*see* **5.4.2.4**) of such pipes for compliance with **4.2**.

Where cathodic protection is applied and the exposed-conductive-part of an item of electrical equipment supplied by a TT system is directly connected to the pipe, a metallic pipe for flammable liquids or gases may act as the sole earth electrode for this specific equipment.

5.4.2.3 *Earthing conductors*

5.4.2.3.1 Earthing conductors shall comply with **5.4.3.1.1** or **5.4.3.1.2**. Their cross-sectional area shall be not less than 6 mm^2 for copper or 50 mm^2 for steel. Where a bare earthing conductor is buried in the soil, its dimensions and characteristics shall also be in accordance with Table 13.

Where no noticeable fault current is expected to flow through the earth electrode (for example, in TN systems or IT systems), the earthing conductor may be dimensioned according to **5.4.4.1**.

Aluminium conductors shall not be used as earthing conductors.

NOTE — Where a lightning protection system is connected to the earth electrode, the cross-sectional area of the earthing conductor should be at least 16 mm^2 for copper (Cu) or 50 mm^2 for iron (Fe) (*see* IS/IEC 62305 series).

5.4.2.3.2 The connection of an earthing conductor to an earth electrode shall be soundly made and electrically satisfactory. The connection shall be by exothermic welding, pressure connectors, clamps or other suitable mechanical connectors. Mechanical

Table 13 Minimum Size of Commonly Used Earth Electrodes, Embedded in Soil or Concrete Used to Prevent Corrosion and Provide Mechanical Strength
(*Clause* 5.4.2.3.1)

Material and Surface	Shape	Diameter mm	Cross-Sectional Area mm^2	Thickness mm	Weight of Coating g/m^2	Thickness of Coating/ Sheathing µm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Steel embedded in concrete (bare, hot galvanized or stainless)	Round wire	10				
	Solid tape or strip		75	3		
Steel hot-dip galvanized[3]	Strip[2] or shaped strip/plate – Solid plate – Lattice plate		90	3	500	63
	Round rod installed vertically	16			350	45
	Round wire installed horizontally	10			350	45
	Pipe	25		2	350	45
	Stranded (embedded in concrete)		70			
	Cross profile installed vertically		(290)	3		
Steel copper-sheathed	Round rod installed vertically	(15)				2 000
Steel with electro-deposited copper coating	Round rod installed vertically	14				250[5]
	Round wire installed horizontally	(8)				70
	Strip installed horizontally		90	3		70
Stainless steel[1]	Strip[2] or shaped strip/plate		90	3		
	Round rod installed vertically	16				
	Round wire installed horizontally	10				
	Pipe	25		2		
Copper	Strip		50	2		
	Round wire installed horizontally		(25)[4]50			
	Solid round rod installed vertically	(12) 15				
	Stranded wire	1.7 for individual strands of wire	(25)[4] 50			
	Pipe	20		2		
	Solid plate			(1.5) 2		
	Lattice plate			2		

NOTE — Values in brackets are applicable for protection against electric shock only, while values not in brackets are applicable for lightning protection and for protection against electric shock.

[1] Chromium ≥16 %, Nickel ≥ 5 %, Molybdenum ≥2 %, Carbon ≤ 0.08 %.
[2] As rolled strip or slit strip with rounded edges.
[3] The coating shall be smooth, continuous and free from flux stains.
[4] Where experience shows that the risk of corrosion and mechanical damage is extremely low, 16 mm² can be used.
[5] This thickness is provided to withstand mechanical damage of copper coating during the installation process. It may be reduced to not less than 100 µm where special precautions to avoid mechanical damage of copper during the installation process (for example, drilled holes or special protective tips) are taken according to the manufacturer's instructions.

connectors shall be installed in accordance with the manufacturer's instructions. Where a clamp is used, it shall not damage the electrode or the earthing conductor.

Connection devices or fittings that depend solely on solder shall not be used independently, as they do not reliably provide adequate mechanical strength.

NOTE — Where vertical electrodes are installed, means may be provided to allow the inspection of the connection and there placement of the vertical rod.

5.4.2.4 *Main earthing terminal*

5.4.2.4.1 In every installation where protective equipotential bonding is used, a main earthing terminal shall be provided and the following shall be connected to it:

a) protective bonding conductors;
b) earthing conductors;
c) protective conductors;
d) functional earthing conductors, if relevant.

NOTES

1 It is not intended to connect every individual protective conductor directly to the main earthing terminal where they are connected to this terminal by other protective conductors.

2 The main earthing terminal of the building can generally be used for functional earthing purposes. For information technology purposes, it is then regarded as the connection point to the earth.

Where more than one earthing terminal is provided, they shall be interconnected.

5.4.2.4.2 Each conductor connected to the main earthing terminal shall be able to be disconnected individually. This connection shall be reliable and such that it can only be disconnected by means of a tool.

NOTE — Disconnection means may conveniently be combined with the main earthing terminal, to permit measurement of the resistance of the earth electrode.

5.4.3 *Protective Conductors*

NOTE — Consideration should be given to requirements given in **5.1.6**.

5.4.3.1 *Minimum cross-sectional areas*

5.4.3.1.1 The cross-sectional area of every protective conductor shall satisfy the conditions for automatic disconnection of supply required in **4.2.11.3.2** and be capable of withstanding mechanical and thermal stresses caused by the prospective fault current during the disconnection time of the protective device.

The cross-sectional area of a protective conductor shall either be calculated in accordance with **5.4.3.1.2**, or selected in accordance with Table 14. In either case, the requirements of **5.4.3.1.3** shall be taken into account.

Terminals for protective conductors shall be capable of accepting conductors of dimensions required by this sub-clause.

In TT systems, where the earth electrodes of the supply system and of the exposed conductive parts are electrically independent, the cross-sectional area of protective conductors need not exceed:

– 25 mm^2 copper,
– 35 mm^2 aluminium.

Table 14 Minimum Cross-Sectional Area of Protective Conductors
(where not calculated in accordance with 5.4.3.1.2)
(*Clause* 5.4.3.1.1)

Cross-sectional Area of Line Conductor, S (mm^2 Cu)	**Minimum Cross-Sectional Area of the Corresponding Protective Conductor** (mm^2 Cu)	
	If the protective conductor is of the same material as the line conductor	If the protective conductor is not of the same material as the line conductor
(1)	(2)	(3)
$S \leq 16$	S	$\frac{k_1}{k_2} \times S$
$16 < S \leq 35$	16[1)]	$\frac{k_1}{k_2} \times 16$
$S > 35$	$\frac{S}{2}$[1)]	$\frac{k_1}{k_2} \times \frac{S}{2}$

where

k_1 = is the value of k for the line conductor derived from the formula given in Annex A or selected from tables given in IEC 60364-4-43, according to the materials of the conductor and insulation;

k_2 = is the value of k for the protective conductor, selected from Tables 58 to Table 62 as applicable.

1) For a PEN conductor, the reduction of the cross-sectional area is permitted only in accordance with the rules for sizing of the neutral conductor (*see* **5.2**).

5.4.3.1.2 The cross-sectional areas of protective conductors shall be not less than the value determined either:

a) in accordance with IEC 60949; or
b) by the following formula applicable only for disconnection times not exceeding 5 s:

$$S = \frac{\sqrt{I^2 t}}{k}$$

where

S = the cross-sectional area in mm^2;

I = the r.m.s value expressed in amperes of prospective fault current, for a fault of negligible impedance, which can flow through the protective device (IS/IEC 60909-0);

t = the operating time in seconds of the protective device for automatic disconnection; and

k = the factor dependent on the material of the protective conductor, the insulation and other parts and the initial and final temperatures (for calculation of k, *see* Annex EE).

Where the application of the formula produces a non-standard size, a conductor having at least the nearest larger standard cross-sectional area shall be used.

NOTES

1 Account should be taken of the current-limiting effect of the circuit impedances and the limitation of I^2t of the protective device.

2 For limitations of temperatures for installations in potentially explosive atmospheres (*see* IS/ IEC 60079-0).

3 As the metallic sheaths of mineral-insulated cables according to IEC 60702-1 have an earth fault capacity greater than that of the line conductors, it is not necessary to calculate the cross-sectional area of the metallic sheaths when used as protective conductors.

5.4.3.1.3 The cross-sectional area of every protective conductor which does not form part of a cable or which is not in a common enclosure with the line conductor shall be not less than:

a) 2.5 mm^2 Cu or 16 mm^2 Al, if protection against mechanical damage is provided; and
b) 4 mm^2 Cu or 16 mm^2 Al, if protection against mechanical damage is not provided.

NOTE — The use of steel for a protective conductor is not excluded (*see* **5.4.3.1.2**).

A protective conductor not forming part of a cable is considered to be mechanically protected if it is installed in a conduit, trunking or protected in a similar way.

5.4.3.1.4 Where a protective conductor is common to two or more circuits, its cross-sectional area shall be:

a) calculated in accordance with **5.4.3.1.2** for the most onerous prospective fault current and operating time encountered in these circuits; or
b) selected in accordance with Table 14 so as to correspond to the cross-sectional area of the largest line conductor of the circuits.

5.4.3.2 *Types of protective conductors*

5.4.3.2.1 Protective conductors may consist of one or more of the following:

a) conductors in multicore cables;
b) insulated or bare conductors in a common enclosure with live conductors;
c) fixed installed bare or insulated conductors;
d) metallic cable sheath, cable screen, cable armour, wirebraid, concentric conductor, metallic conduit, subject to the conditions stated in **5.4.3.2.2**(a) and (b).

NOTE — *See* **5.4.3.8** for their arrangement.

5.4.3.2.2 Where the installation contains equipment having metal enclosures such as low-voltage switchgear and controlgear assemblies (*see* IS/IEC 61439-1 and IS/IEC 61439-2) or busbar trunking systems (IS/ IEC 60439-2), their metal enclosures or frames may be used as protective conductors if they simultaneously satisfy the following three requirements:

a) their electrical continuity shall be assured by construction or by suitable connection so as to ensure protection against mechanical, chemical or electrochemical deterioration;
b) they comply with the requirements of **5.4.3.1**;
c) they shall permit the connection of other protective conductors at every predetermined tap-off point.

5.4.3.2.3 The following metal parts are not permitted for use as protective conductors or as protective bonding conductors:

a) metallic water pipes;
b) metallic pipes containing potentially flammable materials such as gases, liquids, powder;

NOTES

1 For cathodic protection, *see* **5.4.2.2.2**.

i) constructional parts subject to mechanical stress in normal service;

ii) flexible or pliable metal conduits, unless designed for that purpose;

iii) flexible metal parts; and

iv) support wires; cable trays and cable ladders.

2 Examples of a protective conductor include a protective bonding conductor, a protective earthing conductor and an earthing conductor when used for protection against electric shock.

5.4.3.3 *Electrical continuity of protective conductors*

5.4.3.3.1 Protective conductors shall be suitably protected against mechanical damage, chemical or electrochemical deterioration, electrodynamics forces and thermodynamic forces.

Every connection (for example, screwed connections, clamp connectors) between protective conductors or between a protective conductor and other equipment shall provide durable electrical continuity and adequate mechanical strength and protection. Screws for connecting protective conductors shall not serve any other purpose.

Joints shall not be made by soldering.

NOTE — All electrical connections should have satisfactory thermal capacity and mechanical strength to withstand any combination of current/time which may occur in the conductor or in the cable/enclosure with the largest cross-sectional area.

5.4.3.3.2 Joints in protective conductors shall be accessible for inspection and testing except for:

a) compound-filled joints,
b) encapsulated joints,
c) joints in metal conduits, ducting and busbar trunking systems,
d) joints forming part of equipment, complying with equipment standards,
e) joints made by welding or brazing, and
f) joints made by compression tool.

5.4.3.3.3 No switching device shall be inserted in the protective conductor, but joints which can be disconnected for test purposes by use of a tool may be provided.

5.4.3.3.4 Where electrical monitoring of earthing is used, dedicated devices (for example, operating sensors, coils, current transformers) shall not be connected in series in protective conductors.

5.4.3.3.5 Exposed-conductive-parts of electrical equipment shall not be used to form part of the protective conductor for other equipment except as allowed by **5.4.3.2.2**.

5.4.3.4 *PEN, PEL or PEM conductors*

NOTE — As these conductors serve two functions, as PE- and either as N-, L- or M-conductors, all applicable requirements for the relevant functions should be considered.

5.4.3.4.1 A PEN, PEL or PEM conductor may only be used in fixed electrical installations and, for mechanical reasons, shall have a cross-sectional area not less than 10 mm² copper or 16 mm² aluminium.

NOTES

1 For EMC reasons, the PEN conductor should not be installed downstream of the origin of the installation (*see* **4.5.4.4.3.2**).

2 IS/IEC 60079-14 does not permit the use of a PEN, PEL or PEM conductor in explosive atmospheres.

5.4.3.4.2 The PEN, PEL or PEM conductor shall be insulated for the rated voltage of the line conductor.

Metallic enclosures of wiring systems shall not be used as PEN, PEL or PEM conductors, except for busbar trunking systems complying with IS 8623 (Part 2) and for powertrack systems complying with IEC 61534-1.

NOTE — Product committees should consider the potential effect of EMI introduced into the equipment from a PEN, PEL or PEM conductor.

5.4.3.4.3 If, from any point of the installation, the neutral/mid-point/line and protective functions are provided by separate conductors, it is not permitted to connect the neutral/mid-point/line conductor to any other earthed part of the installation. However, it is permitted to form more than one neutral/mid-point/line conductor and more than one protective conductor from the PEN, PEL or PEM conductor respectively.

The PEN, PEL or PEM conductor shall be connected to the terminal or bar intended for the protective conductors (*see* Fig.61A), unless there is a specific terminal or bar intended for the connection of the PEN, PEL or PEM conductor (examples are given in Fig. 61B and 61C).

NOTE — In systems supplied with SELV direct current, for example, telecommunication systems, there is no PEL or PEM conductor.

5.4.3.4.4 Extraneous-conductive-parts shall not be used as PEN, PEL or PEM conductors.

5.4.3.5 *Combined protective and functional earthing conductors*

Where a combined protective and functional earthing conductor is used, it shall satisfy the requirements for a protective conductor. In addition, it shall also comply with the relevant functional requirements (*see* **4.5.4**).

A d.c. return conductor PEL or PEM for an information technology power supply may also serve as a combined functional earthing and protective conductor.

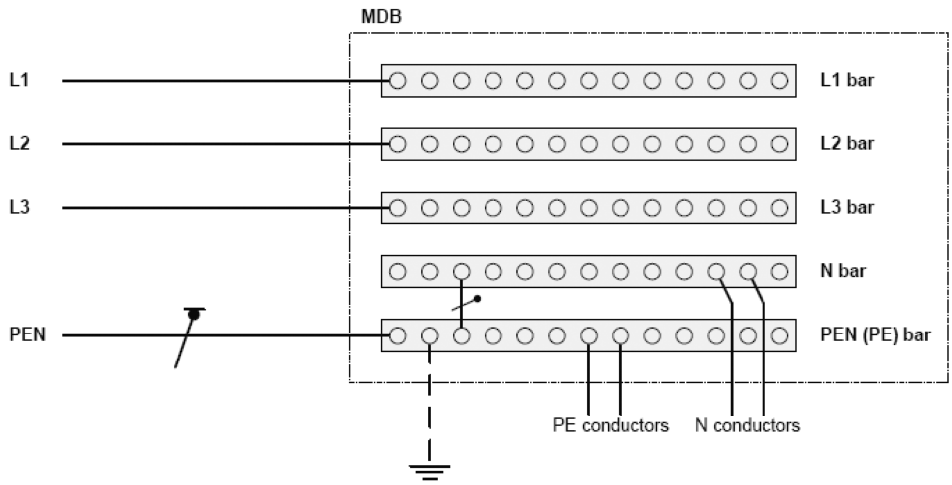
NOTE — For further information, *see* IEC 61140.

5.4.3.6 *Currents in protective earthing conductors*

The protective earthing conductor should not be used as a conductive path for current under normal operating conditions (for example, connection of filters for EMC-reasons), *see also* IEC 61140.

Where the current exceeds 10 mA under normal operating conditions, a reinforced protective conductor shall be used (*see* **5.4.3.7**).

NOTE — Capacitive leakage currents, for example, by cables or motors, should be reduced by the design of the installation and the equipment.



61A Example 1

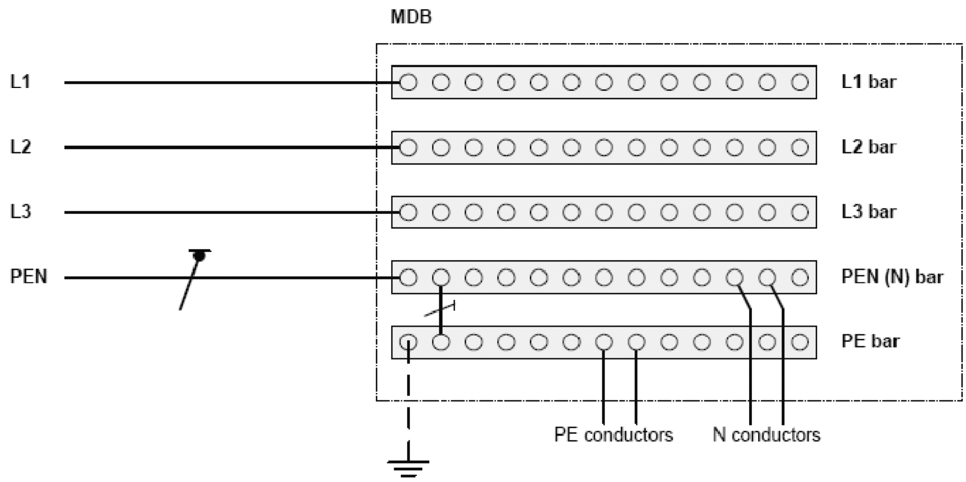


Fig. 61B Example 2

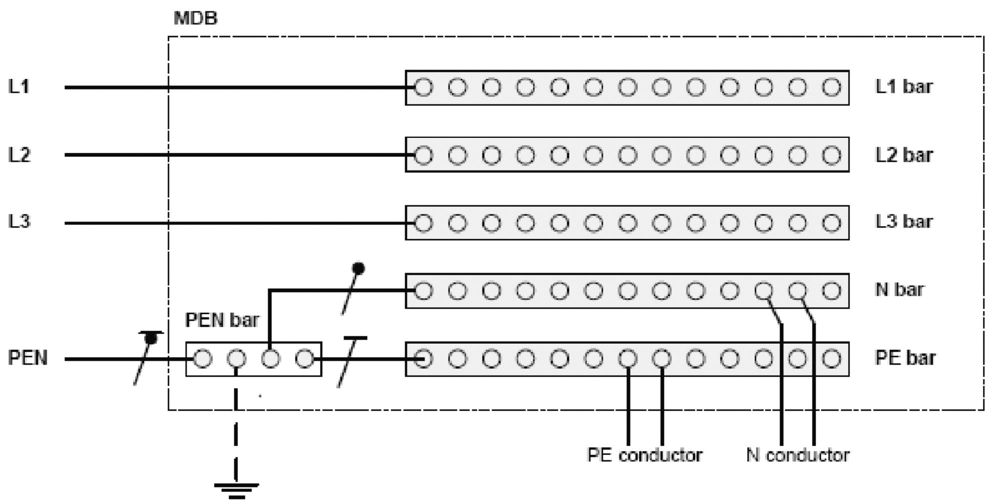


Fig.61C Example 3

KEY

MDB—main distribution board

FIG. 61 EXAMPLES OF A PEN CONDUCTOR CONNECTION

5.4.3.7 *Reinforced protective earthing conductors for protective earthing conductor currents exceeding 10 mA*

For current-using equipment intended for permanent connection and with a protective earthing conductor current exceeding 10 mA the following applies:

a) where the current-using equipment has only one protective earthing terminal, the protective earthing conductor shall have a cross-sectional area of at least 10 mm^2 Cu or 16 mm^2 Al, through its total run;

NOTE — A PEN, PEL or PEM conductor in accordance with **5.4.3.4** complies with this requirement.

b) where the current-using equipment has a separate terminal for a second protective earthing conductor a second protective earthing conductor of at least the same cross-sectional area as required for fault protection shall be run from a point where the protective earthing conductor has a cross-sectional area not less than 10 mm^2 Cu or 16 mm^2 Al.

NOTES

1 In TN-C systems where the neutral and protective conductors are combined in a single conductor (PEN conductor) up to the equipment terminals, protective conductor current may be treated as load current.

2 Current-using equipment normally having high protective conductor current may not be compatible with installations incorporating residual current protective devices.

5.4.3.8 *Arrangement of protective conductors*

Where overcurrent protective devices are used for protection against electric shock, the protective conductor shall be incorporated in the same wiring system as the live conductors or be located in their immediate proximity.

5.4.4 *Protective Bonding Conductors*

5.4.4.1 *Protective bonding conductors for connection to the main earthing terminal*

Protective bonding conductors for connection to the main earthing terminal shall have a cross-sectional area not less than half the cross-sectional area of the largest protective earthing conductor within the installation and not less than:

a) 6 mm^2 copper; or
b) 16 mm^2 aluminium; or
c) 50 mm^2 steel.

The cross-sectional area of protective bonding conductors for connection to the main earthing terminal need not exceed 25 mm^2 Cu or an equivalent cross-sectional area for other materials.

5.4.4.2 *Protective bonding conductors for supplementary bonding*

5.4.4.2.1 A protective bonding conductor connecting two exposed conductive parts shall have a conductance not less than that of the smaller protective conductor connected to the exposed conductive parts.

5.4.4.2.2 A protective bonding conductor connecting exposed conductive parts to extraneous conductive parts shall have a conductance not less than half that of the cross-sectional area of the corresponding protective conductor.

5.4.4.2.3 The minimum cross-sectional area of protective bonding conductors for supplementary bonding, and of bonding conductors between two extraneous conductive parts, shall be in accordance with **5.4.3.1.1**.

5.5 Selection and Erection of Electrical Equipment — Other Equipment

5.5.1 *Void*

5.5.2 *Low-Voltage Generating Sets*

5.5.2.1 *General*

This clause provides requirements for the selection and erection of low-voltage and extra-low voltage generating sets intended to supply, either continuously or occasionally, all or part of the installation. Requirements are also included for installations with the following supply arrangements:

a) supply to an installation which is not connected to a system for distribution of electricity to the public;
b) supply to an installation as an alternative to a system for distribution of electricity to the public;
c) supply to an installation in parallel with a system for distribution of electricity to the public supply; and
d) appropriate combinations of the above.

This part does not apply to self-contained items of extra-low voltage electrical equipment which incorporate both the source of energy and the energy-using load and for which a specific product standard exists that includes the requirements for electrical safety.

NOTE — Requirements of the electricity distributor should be ascertained before a generating set is installed in an installation that is connected to a system for distribution of electricity to the public.

5.5.2.1.1 Generating sets with the following power sources are considered:

a) combustion engines;

b) turbines;
c) electric motors;
d) photovoltaic cells [IEC 60364-7-712 also applies];
e) electrochemical accumulators; and
f) other suitable sources.

5.5.2.1.2 Generating sets with the following electrical characteristics are considered:

a) mains-excited and separately excited synchronous generators;
b) mains-excited and self-excited asynchronous generators;
c) mains-commutated and self-commutated static converters with or without by-pass facilities; and
d) generating sets with other suitable electrical characteristics.

5.5.2.1.3 The use of generating sets for the following purposes is considered:

a) supply to permanent installations;
b) supply to temporary installations;
c) supply to portable equipment which is not connected to a permanent installation; and
d) supply to mobile [IEC 60364-7-712 also applies].

5.5.2.2 *General requirements*

5.5.2.2.1 The means of excitation and commutation shall be appropriate for the intended use of the generating set and the safety and proper functioning of other sources of supply shall not be impaired by the generating set.

NOTE — *See* **5.5.2.7** for particular requirements where the generating set may operate in parallel with a system for the distribution of electricity to the public.

5.5.2.2.2 The prospective short-circuit current and prospective earth fault current shall be assessed for each source of supply or combination of sources which can operate independently of other sources or combinations. The short-circuit breaking capacity of protective devices within the installation and, where appropriate, connected to a system for distribution of electricity to the public, shall not be exceeded for any of the intended methods of operation of the sources.

NOTE — Attention should be given to the power factor specified for protective devices in the installation.

5.5.2.2.3 The capacity and operating characteristics of the generating set shall be such that danger or damage to equipment does not arise after the connection or disconnection of any intended load as a result of the deviation of the voltage or frequency from the intended operating range. Means shall be provided to automatically disconnect such parts of the installation as may be necessary if the capacity of the generating set is exceeded.

NOTES

1 Attention should be given to the size of individual loads as a proportion of the capacity of the generating set and to motor starting currents.

2 Attention should be given to the power factor specified for protective devices in the installation.

3 The installation of a generating set within an existing building or installation may change the conditions of external influence for the installation (*see* **4**), for example by the introduction of moving parts, parts at high temperature or by the presence of inflammable fluids and noxious gases, etc.

5.5.2.2.4 Provision for isolation shall meet the requirements of **5.3.7** for each source or combination of sources of supply.

5.5.2.3 *Protective measure: extra-low-voltage provided by SELV and PELV*

5.5.2.3.1 *Additional requirements for SELV and PELV where the installation is supplied from more than one source*

Where a SELV or PELV system may be supplied by more than one source, the requirements of **4.2.14.3** shall apply to each source. Where one or more of the sources is earthed, the requirements for PELV systems in **4.2.14** shall apply.

If one or more of the sources does not meet the requirements of **4.2.14.3**, the system shall be treated as a FELV system and the requirements of **4.2.11.7** shall apply.

5.5.2.3.2 *Additional requirements where it is necessary to maintain the supply to an extra-low voltage system*

Where it is necessary to maintain the supply to an extra-low voltage system following the loss of one or more sources of supply, each source of supply or combination of sources of supply which can operate independently of other sources or combinations shall be capable of supplying the intended load of the extra-low voltage system. Provisions shall be made so that the loss of low-voltage supply to an extra-low voltage source does not lead to danger or damage to other extra-low voltage equipment.

NOTE — Such precautions may be necessary in supplies for safety services (*see***4.1.5.14**).

5.5.2.4 *Fault protection (protection against indirect contact)*

5.5.2.4.1 Fault protection shall be provided for the installation in respect of each source of supply or combination of sources of supply that can operate independently of other sources or combinations of sources.

The fault protective provisions shall be selected or precautions shall be taken to ensure that where fault protective provisions are achieved in different ways within the same installation or part of an installation according to the active sources of supply, no influence shall occur or conditions arise that could impair the effectiveness of the fault protective provisions.

NOTE — This might, for example, require the use of a transformer providing electrical separation between parts of the installation using different earthing systems.

5.5.2.4.2 The generating set shall be connected so that any provision within the installation for protection by residual current devices in accordance with **4.2** remains effective for every intended combination of sources of supply.

NOTE — Connection of live parts of the generator with earth may affect the protective measures.

5.5.2.4.3 *Protection by automatic disconnection of supply*

5.5.2.4.3.1 *General*

Where the protective measure automatic disconnection of supply is used for protection against electric shock, the requirements of **4.2.11** apply, except as modified for the particular cases given in **5.5.2.4.3.2** or **5.5.2.4.3.3**.

5.5.2.4.3.2 *Additional requirements for installations where the generating set provides a supply as a switched alternative to the normal supply to the installation*

Protection by automatic disconnection of supply shall not rely upon the connection to the earthed point of the distribution system when the generator is operating as a switched alternative. A suitable means of earthing shall be provided.

5.5.2.4.3.3 *Additional requirements for installations incorporating static converters*

5.5.2.4.3.3.1 Where fault protection for parts of the installation supplied by the static converter relies upon the automatic closure of the by-pass switch and the operation of protective devices on the supply side of the by-pass switch is not within the time required by **4.2.11**, supplementary equipotential bonding shall be provided between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts on the load side of the static converter in accordance with **4.2.15.2**.

The resistance of supplementary equipotential bonding conductors required between simultaneously accessible conductive parts shall fulfil the following condition:

$$R \leq \frac{50\text{V}}{I_a}$$

where

I_a = the maximum earth fault current which can be supplied by the static converter alone for a period of up to 5 s.

NOTE — Where such equipment is intended to operate in parallel with a system for distribution of electricity to the public, the requirements of **5.5.2.7** also apply.

5.5.2.4.3.3.2 Precautions shall be taken or equipment shall be selected so that the correct operation of protective devices is not impaired by d.c. currents generated by a static converter or by the presence of filters.

5.5.2.4.3.3.3 A means of isolation shall be installed on both sides of a static converter**.**

This requirement does not apply on the power source side of a static converter which is integrated in the same enclosure as the power source.

5.5.2.5 *Protection against overcurrent*

5.5.2.5.1 Where overcurrent protection of the generating set is required, it shall be located as near as practicable to the generator terminals.

NOTE — The contribution to the prospective short-circuit current by a generating set may be time-dependent and may be much less than the contribution made by a system where the source is a mv/lv transformer.

5.5.2.5.2 Where a generating set is intended to operate in parallel with another source of supply, including a supply from a system for distribution of electricity to the public, or where two or more generating sets may operate in parallel, harmonic currents shall be limited so that the thermal rating of conductors is not exceeded.

The effects of harmonic currents may be limited as follows:

a) the selection of generating sets with compensated windings;
b) the provision of a suitable impedance in the connection to generator star points;
c) the provision of switches which interrupt the circuit but which are interlocked so that at all times fault protection is not impaired;
d) the provision of filtering equipment; and
e) other suitable means.

NOTES

1 Consideration should be given to the maximum voltage which may be produced across an impedance connected tolimit harmonics.

2 Monitoring equipment complying with IEC 61557-12 provides information on level of disturbances resulting from the presence of harmonics.

5.5.2.6 *Additional requirements for installations where the generating set provides a supply as a*

switched alternative to the normal supply to the installation

5.5.2.6.1 Precautions complying with the relevant requirements of **5.3** for isolation shall be taken, so that the generator cannot operate in parallel with the public supply system for distribution of electricity to the public. Suitable precautions may include:

a) an electrical, mechanical or electro-mechanical interlock between the operating mechanisms or control circuits of the change-over switching devices;
b) a system of locks with a single transferable key;
c) a three-position, break-before-make, change-over switch;
d) an automatic change-over switching device with a suitable interlock; and
e) other means providing equivalent security of operation.

NOTE — Isolation should include supplies to the control circuits of the generator.

5.5.2.6.2 For TN-S systems where the neutral is not switched, any residual current device shall be positioned to avoid incorrect operation due to the existence of any parallel neutral-earth path.

NOTE — It may be desirable in TN systems to disconnect the neutral of the installation from the neutral or PEN of the system for distribution of electricity to the public to avoid disturbances such as induced voltage surges caused by lightning (*see also* **4.5.4.4.7**).

5.5.2.7 *Additional requirements for installations where the generating set may operate in parallel with other sources including systems for distribution of electricity to the public*

5.5.2.7.1 Where a generating set is used as an additional source of supply in parallel with another source, protection against thermal effects in accordance with **4.3** and protection against overcurrent in accordance with **4.4** shall remain effective in all situations.

Except where an uninterruptible power supply is provided to supply specific items of current using equipment within the final circuit to which it is connected, such a generating set shall be installed on the supply side of all the protective devices for the final circuits of the installation.

5.5.2.7.2 A generating set used as an additional source of supply in parallel with another source shall be installed:

a) on the supply side of all the protective devices for the final circuits of the installation, or
b) on the load side of all the protective devices for a final circuit of the installation, but in this case all the following additional requirement shall be fulfilled:

1) the conductors of the final circuit shall meet the following requirement:

$$I_Z \geq I_n + I_g$$

where

I_Z = the current-carrying capacity of the final circuit conductors;

I_n = the rated current of the protective device of the final circuit; and

I_g = the rated output current of the generating set.

2) a generating set shall not be connected to a final circuit by means of a plug and socket;
3) a residual current device providing protection of the final circuit in accordance with **4.2.11** or **4.2.15** shall disconnect all live conductors including the neutral conductor; and
4) the line and neutral conductors of the final circuit and of the generating set shall not be connected to earth downstream of the protective device of the final circuit.

NOTE — Where the generating set is installed in a final circuit on the load side of all the protective devices for that final circuit, except where the protective devices for the final circuit disconnect the line and the neutral conductors, the disconnection time in accordance with **4.2.11.3.2** is the combination of the disconnection time of the protective device for the final circuit and the time taken for the output voltage of the generating set to be reduced to less than 50 V.

5.5.2.7.3 In selecting and using a generating set to run in parallel with another source, including the system for distribution of electricity to the public, care shall be taken to avoid adverse effects to that system and to other installations in respect of power factor, voltage changes, harmonic distortion, d.c. current injection, unbalance, starting, synchronizing or voltage fluctuation effects. In the case of a system for distribution of electricity to the public, the distributor shall be consulted in respect of particular requirements. Where synchronization is necessary, the use of automatic synchronizing systems which consider frequency, phase and voltage is to be preferred.

5.5.2.7.4 Where a generating set is intended to run in parallel with the system for distribution of electricity to the public, means of automatic switching shall be provided to disconnect the generating set from the system for distribution of electricity to the public in the event of loss of that supply or deviation of the voltage or frequency at the supply terminals from values declared for normal supply.

The type of protection and the sensitivity and operating times depend upon the protection of the system for distribution of electricity to the public and the number of generating sets connected and shall be agreed by the distributor.

In case of presence of static converters, the means of switching shall be provided on the load side of this static converter.

5.5.2.7.5 Where a generating set is intended to run in parallel with the system for distribution of electricity to the public, means shall be provided to prevent the connection of a generating set to the system for distribution of electricity to the public in the event of loss of that supply or deviation of the voltage or frequency at the supply terminals from values declared for normal supply.

5.5.2.7.6 Where a generating set is intended to run in parallel with the system for distribution of electricity to the public, means shall be provided to enable the generating set to be isolated from the system for distribution of electricity to the public. The accessibility of this means of isolation shall comply with national rules and distribution system operator requirements.

5.5.2.7.7 Where a generating set may also operate as switched alternative to the distribution system, the installation shall also comply with **5.5.2.6**.

5.5.2.8 *Requirements for installations incorporating stationary batteries*

5.5.2.8.1 Stationary batteries shall be installed so that they are accessible only to skilled or instructed persons.

NOTE — This generally requires the battery to be installed in a secure location, or, for smaller batteries, a secure enclosure.

The location or enclosure shall be adequately ventilated.

5.5.2.8.2 Battery connections shall have basic protection by insulation or enclosures or shall be arranged so that two bare conductive parts having between them a potential difference exceeding 120 V cannot be inadvertently touched simultaneously.

5.5.3 *Luminaires and Lighting Installations*

5.5.3.1 *Scope*

The particular requirements of this clause apply to the selection and erection of luminaires and lighting installations intended to be part of the fixed installation.

Additional requirements for specific types of lighting installations are covered in:

a) IEC 60364-7-702 for installations in swimming pools and fountains;
b) IEC 60364-7-711 for installations in exhibitions, shows and stands;
c) IEC 60364-7-713 for electrical installations in furniture;
d) IEC 60364-7-714 for outdoor lighting installations; and
e) IEC 60364-7-715 for extra-low-voltage lighting installations.

The requirements of this clause do not apply to:

a) high-voltage signs supplied at low voltage (called neon-tube);

   NOTE — Requirements for high-voltage signs supplied at low voltage (called neon-tube) are included in IEC 60598-214.
b) signs and luminous-discharge-tube installations operating from a no-load rated output voltage exceeding 1 kV but not exceeding 10 kV; and
c) temporary festoon lighting.

   NOTE — Safety requirements for luminaires are covered by IEC 60598 series.

5.5.3.2 *Terms and definitions*

For the purposes of this clause, the general terms and definitions of **4.1**, IS 10322series, IEC 60050-195, IEC 60050-826 and IEC 60570, as well as the following shall apply.

5.5.3.2.1 *Luminaire*

Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply.

5.5.3.2.2 *Display stands for luminaires*

Permanent stands in sales rooms or part of sales rooms which are used to display luminaires.

NOTE — The following items are not regarded as display stands:

a) trade fair stands, in which luminaires remain connected for the duration of the fair;

b) temporary exhibition panels with permanently connected luminaires; and

c) exhibition panels with a range of luminaires which can be connected with a plug-in device.

5.5.3.3 *General requirements for installations*

Luminaires shall be selected and erected in accordance with the manufacturer's instructions and shall comply with IS 10322 series. An electrical supply track system for luminaires shall comply with the requirements of IEC 60570.

NOTES

1 Refer to **5.1.2.1.5** regarding compatibility such as between lamp and control devices. During the installation process of

luminaires the following items shall at least be considered:

a) starting current;

b) harmonics current;

c) compensation;

d) leakage current;

e) primer ignition current; and

f) voltage dip withstand.

2 Concerning the right selection of the protection and control devices, information about the currents relevant to all frequency generated by lamps and for all transient currents should be provided.

3 *See* Annex GG for an explanation of symbols used in luminaires, in controlgear for luminaires and in the installation of the luminaires.

For the purposes of this clause, luminaires without transformer/converter and used with extra-low-voltage (ELV) lamps connected in series shall be considered as low-voltage equipment and not as ELV equipment. These luminaires shall be either Class I or Class II equipment.

A luminaire installed in a pelmet or other architectural or decorative building element shall be selected and erected such that it shall not be adversely affected by the presence and/or operation of curtains or blinds and shall not present a risk of fire or electric shock in normal use.

5.5.3.4 *Protection of the surroundings against thermal effects*

In the selection and erection of luminaires the thermal effect of radiant and convection energy on the surroundings shall be taken into account, including:

a) the maximum permissible power dissipated by the lamps;

NOTE — The maximum permissible power dissipated by the lamps is found on the luminaire.

b) the resistance to heat of adjacent material
- at the point of installation,
- in the thermally affected areas;

c) the minimum distance to combustible materials, including those in the path of a spotlight beam; and

d) the relevant markings on the luminaire.

NOTE — *See* Annex GG for thermal effects markings and symbols.

Additional requirements regarding protection against thermal effects for luminaires may be found in **4.3.2.3** and **4.3.2.4**.

5.5.3.5 *Wiring systems for lighting installations*

5.5.3.5.1 *Connection to the fixed wiring*

Wiring systems shall be terminated in

a) a box, which shall comply with the relevant part of IS 14772; or

b) a device for connecting a luminaire (DCL) outlet according to IEC 61995 mounted in a box; or

c) electrical equipment designed to be connected directly to the wiring system.

5.5.3.5.2 *Fixing of the luminaire*

It shall be ensured that adequate means to fix the luminaire to a stable element of the construction are provided.

The fixing means may be mechanical accessories (for example, hooks or screws), boxes or enclosures which are able to support luminaires (*see* IS 14772) or supporting devices for connecting a luminaire.

The fixing means shall be capable of supporting a mass of not less than 5 kg. Where the mass of the luminaire is greater than 5 kg, the installer shall ensure that the fixing means is capable of supporting the mass of the luminaire.

The installation of the fixing means shall be in accordance with the manufacturer's instructions.

The weight of luminaires, boxes, their fixing means and the eventual accessories shall be compatible with the mechanical capability of the supporting structure.

NOTE — In these conditions, a ceiling or a suspended ceiling may be considered as a stable element of the construction and consequently luminaires may be fixed onto them.

Any cable or cord between the fixing means and the luminaire shall be installed so that any expected stresses in the conductors, terminals and terminations will not impair the safety of the installation (*see also* **5.2.5.8**).

5.5.3.5.3 *Through wiring*

The installation of through wiring in a luminaire is only allowed for luminaire designed for through wiring.

Where connecting devices are required but not provided with the luminaire designed for through wiring, the connecting devices shall be:

a) terminals used for the connection to the supply according to IEC 60998, or

b) installation couplers used for the connection of through wiring according to IEC 61535, or

c) other suitable and appropriate connecting devices.

Cables for through wiring shall be selected in accordance with the temperature information, if provided, on the luminaire or on the manufacturer's instruction sheet:

a) for luminaires complying with IS 10322 but with temperature marking, cables suitable for the marked temperature shall be used;

b) for luminaires complying with IS 10322 but with no temperature marking, heat-resistant cables are not required unless specified in the manufacturer's instructions; and
c) in the absence of information, heat-resistant cables and/or insulated conductors in accordance with IEC 60245-3 or those of an equivalent type shall be used.

NOTE — The temperature marking on the luminaire indicates the maximum temperature according to Table **12.2** of IS 10322 and is marked with the symbol (*see* Annex GG).

5.5.3.5.4 *Devices for connection to the supply*

If the luminaire does not provide connecting devices for connection to the supply, the connecting devices shall be:

a) terminals used for the connection to the supply according to IEC 60998; or
b) devices for connecting a luminaire (DCL) plug according to IEC 61995; or
c) installation couplers used for the connection to the supply according to IEC 61535; or
d) other suitable and appropriate connecting devices.

NOTE — For the installation of the supply cables, *see also* **5.2.4**.

5.5.3.5.5 *Groups of luminaires*

Groups of luminaires divided between the three line conductors of a three-phase circuit with only one common neutral conductor shall be provided with at least one device disconnecting simultaneously all line conductors (*see also* **5.3.6**).

5.5.3.5.6 *Protection against heat and UV radiation effects within the luminaire*

External cables and cores of cables connected within a luminaire or passing through shall be so selected and erected that they will not suffer damage or deterioration due to heat and UV radiation generated by the luminaire or its lamps (for example, shielding).

5.5.3.6 *Independent lamp controlgear, for example, ballasts*

Only independent lamp controlgear marked as suitable for independent use, according to the relevant standard, shall be used external to a luminaire.

NOTE — The generally recognised symbol is: independent ballast standard IEC 60417-5138 (2011-01).

Only the following are permitted to be mounted on flammable surfaces:

a) a "class P" thermally protected ballast(s)/transformer(s), marked with the symbol ; or
b) a temperature declared thermally protected ballast(s)/transformer(s), marked with the symbol .

5.5.3.7 *Compensation capacitors*

Compensation capacitors having a total capacitance exceeding 0.5 μF shall only be used in conjunction with discharge resistors in accordance with the requirements of IS 1569.

5.5.3.8 *Protection against electric shock for display stands for luminaires*

Protection against electric shock for circuits supplying display stands for luminaires shall be provided by either;

a) SELV or PELV supply, or
b) a residual current operated protective device having a rated residual operating current not exceeding 30 mA which provides both automatic disconnection of supply according to **4.2.11** and additional protection according to **4.2.15.1**.

5.5.3.9 *Stroboscopic effect*

In the case of lighting for premises where machines with moving parts are in operation, consideration shall be given to stroboscopic effects which can give a misleading impression of moving parts being stationary. Such effects may be avoided by selecting luminaires with suitable lamp controlgear (for example, high frequency electronic controlgear).

5.5.3.10 *Ground recessed luminaires*

The requirements as given in IS 10322 series shall be fulfilled by the selection and erection of ground recessed luminaires.

5.6 Selection and Erection of Electrical Equipment — Safety Services

5.6.1 *Void*

5.6.2 *Classification*

5.6.2.1 An electrical supply system for safety services is either:

a) a non-automatic supply, the starting of which is initiated by an operator, or
b) an automatic supply, the starting of which is independent of an operator.

An automatic supply is classified as follows, according to the maximum changeover time:

a) *no-break*: an automatic supply which can ensure a continuous supply within specified conditions during the period of transition, for example as regards variations in voltage and frequency;
b) *Very short break*: an automatic supply available within 0.15 s;
c) *Short break*: an automatic supply available within 0.5 s;
d) *Average break*: an automatic supply available within 5 s;
e) *Medium break*: an automatic supply available within 15 s; and
f) *Long break*: an automatic supply available in more than 15 s.

5.6.2.2 The essential equipment for safety services shall be compatible with the changeover time in order to maintain the specified operation.

5.6.3 *General*

5.6.3.1 Safety services may be required to operate at all relevant times including during main and local supply failure and through fire conditions. To meet these requirements, specific sources, equipment, circuits and wiring are necessary. Some applications also have particular requirements, as given in **5.6.3.2** and **5.6.3.3**.

5.6.3.2 For safety services required to operate in fire conditions, the following additional two conditions shall be fulfilled:

a) an electrical source for safety supply shall be selected in order to maintain a supply of adequate duration, and
b) all equipment of safety services shall be provided, either by construction or by erection, with protection ensuring fire resistance of adequate duration.

NOTE — The electrical safety supply source is generally additional to the normal supply source, for example the public supply network.

5.6.3.3 Where automatic disconnection of supply is used as a protective measure against electric shock, non-disconnection on the first fault is preferred. In IT systems, insulation monitoring devices shall be provided which give an audible and visible indication in the event of a first fault.

5.6.3.4 Regarding control and bus systems, a failure in the control or bus system of a normal installation shall not adversely affect the function of safety services.

5.6.4 *Electrical sources for safety services*

5.6.4.1 The following electrical sources for safety services are recognized:

a) storage batteries;
b) primary cells;
c) generator sets independent of the normal supply; and
d) a separate feeder of the supply network that is effectively independent of the normal feeder.

5.6.4.2 Safety sources for safety services shall be installed as fixed equipment and in such a manner that they cannot be adversely affected by failure of the normal source.

5.6.4.3 Safety sources shall be installed in a suitable location and be accessible only to skilled or instructed persons (BA5 or BA4).

5.6.4.4 The location of the safety source shall be properly and adequately ventilated so that exhaust gases, smoke or fumes from the safety source cannot penetrate areas occupied by persons.

5.6.4.5 Separate, independent feeders from a supply network shall not serve as electrical sources for safety services unless assurance can be obtained that the two supplies are unlikely to fail concurrently.

5.6.4.6 The safety source shall have sufficient capability to supply its related safety service.

5.6.4.7 A safety source may, in addition, be used for purposes other than safety services, provided the availability for safety services is not thereby impaired. A fault occurring in a circuit for purposes other than safety services shall not cause the interruption of any circuit for safety services.

5.6.4.8 *Special requirements for safety sources not capable of operation in parallel*

5.6.4.8.1 Adequate precautions shall be taken to avoid the paralleling of sources.

NOTE — This may be achieved by mechanical interlocking.

5.6.4.8.2 Short-circuit protection and fault protection shall be ensured for each source.

5.6.4.9 *Special requirements for safety services having sources capable of operation in parallel*

NOTE — The parallel operation of independent sources normally requires the authorization of the supply undertaking. This may require special devices, for example to prevent reverse power.

Short-circuit protection and fault protection shall be ensured when the installation is supplied separately by either of the two sources or by both in parallel.

NOTE — Precautions may be necessary to limit current circulation in the connection between the neutral points of the sources, in particular the effect of third harmonics.

5.6.4.10 *Central power supply system*

Batteries shall be of vented or valve-regulated

maintenance-free type and shall be of heavy duty industrial design, for example cells complying with IEC 60623 or the IEC 60896 series.

NOTE — The minimum design life of the batteries at 20 °C should be 10 years.

5.6.4.11 *Low-power supply system*

The power output of a low-power supply system is limited to 500 W for a 3 h duration and 1500 W for a 1 h duration. Batteries can be of gas-tight or valve-regulated maintenance-free type and shall be of heavy duty industrial design, for example cells complying with IEC 60623 or the IEC 60896 series.

NOTE — The minimum design life of the batteries at 20 °C should be 5 years.

5.6.4.12 *Uninterruptible power supply sources*

Where an uninterruptible power supply is used, it shall:

a) be able to operate distribution circuit protective devices,
b) be able to start the safety devices when it is operating in the emergency condition from the inverter supplied by the battery,
c) comply with the requirements of **5.6.4.10**, and
d) comply with IEC 62040-1-1, IEC 62040-1-2 or IEC 62040-3, as applicable.

5.6.4.13 *Safety generating sets*

Where a safety generating set is used as a safety source, it shall comply with ISO 8528-12.

5.6.4.14 The condition of the source for safety services (ready for operation, under fault conditions, feeding from the source for safety services) shall be monitored.

5.6.5 *Circuits of Safety Services*

5.6.5.1 Circuits of safety services shall be independent of other circuits.

NOTE — This means that an electrical fault or any intervention or modification in one system must not affect the correct functioning of the other. This may necessitate separation by fire-resistant materials or different routes or enclosures.

5.6.5.2 Circuits of safety services shall not pass through locations exposed to fire risk (BE2) unless they are fire-resistant. The circuits shall not, in any case, pass through zones exposed to explosion risk (BE3).

NOTE — Where practicable, the passage of any circuit through locations presenting a fire risk should be avoided.

5.6.5.3 According to **4.4.3**, protection against overload may be omitted where the loss of supply may cause a greater hazard. Where protection against overload is omitted, the occurrence of an overload shall be monitored.

5.6.5.4 Overcurrent protective devices shall be selected and erected so as to avoid an overcurrent in one circuit impairing the correct operation of circuits of safety services.

5.6.5.5 Switchgear and controlgear shall be clearly identified and grouped in locations accessible only to skilled or instructed persons (BA5 or BA4).

5.6.5.6 In equipment supplied by two different circuits with independent sources, a fault occurring in one circuit shall not impair the protection against electric shock, nor the correct operation of the other circuit. Such equipment shall be connected to the protective conductors of both circuits, if necessary.

5.6.5.7 Safety circuit cables, other than metallic screened, fire-resistant cables, shall be adequately and reliably separated by distance or by barriers from other circuit cables, including other safety circuit cables.

NOTE — For battery cables, special requirements may apply.

5.6.5.8 Circuits for safety services, with the exception of wiring for fire rescue service lift supply cables, and wiring for lifts with special requirements, shall not be installed in lift shafts or other flue-like openings.

5.6.5.9 In addition to a general schematic diagram, full details of all electrical safety sources shall be given. The information shall be maintained adjacent to the distribution board. A single-line diagram is sufficient.

5.6.5.10 Drawings of the electrical safety installations shall be available showing the exact location of:

a) all electrical equipment and distribution boards, with equipment designations;
b) safety equipment with final circuit designation and particulars and purpose of the equipment; and
c) special switching and monitoring equipment for the safety power supply (for example, area switches, visual or acoustic warning equipment).

5.6.5.11 A list of all the current-using equipment permanently connected to the safety power supply, indicating the nominal electrical power, nominal currents and starting currents and time for current-using equipment, shall be provided.

NOTE — This information may be included in the circuit diagrams.

5.6.5.12 Operating instructions for safety equipment and electrical safety services shall be available. They shall take into account all the particulars of the installation.

5.6.6 *Wiring Systems*

5.6.6.1 One or more of the following wiring systems shall be utilized for safety services required to operate in fire conditions:

a) mineral insulated cable complying with IEC 60702-1 and IEC 60702-2;
b) fire-resistant cables complying with the appropriate part of IEC 60331 and with IEC 60332-1-2; and
c) a wiring system maintaining the necessary fire and mechanical protection.

Wiring systems shall be mounted and installed in such a way that the circuit integrity will not be impaired during the fire.

NOTE — Examples of a system maintaining the necessary fire and mechanical protection could be:

a) constructional enclosures to maintain fire and mechanical protection, or

b) wiring systems in separate fire compartments.

5.6.6.2 Wiring for control and bus systems of safety services shall be in accordance with the same requirements as the wiring which is to be used for the safety services. This does not apply to circuits that do not adversely affect the operation of the safety equipment.

5.6.6.3 Precautions shall be taken to prevent excavation damage to buried safety circuits.

5.6.6.4 Circuits for safety services which can be supplied by direct current shall be provided with two-pole over current protection mechanisms.

5.6.6.5 Switchgear and control gear used for both a.c. and d.c. supply sources shall be suitable for both a.c. and d.c. operation.

5.6.7 *Emergency Escape Lighting Applications*

5.6.7.1 Emergency escape lighting systems may be powered by a central power supply system or the emergency lighting luminaires may be self-contained. The supply to self-contained luminaires is excluded from the requirements of **5.6.7.1** to **5.6.7.4** inclusive.

Wiring systems for a centrally powered emergency lighting system shall retain the continuity of supply from the source to the luminaires for an adequate period in the event of a fire. This shall be achieved by using cables with a high resistance to fire, as detailed in **5.6.6.1** and **5.6.6.2**, to transfer power through a fire compartment.

Within the fire compartment, the supplies to the luminaire shall either use cables with a high resistance to attack by fire or, for compartments having more than one emergency lighting luminaire, such luminaires shall be wired alternately from at least two separate circuits so that a level of illuminance is maintained along the escape route in the event of the loss of one circuit.

5.6.7.2 Where alternate luminaires are supplied by separate circuits overcurrent protective devices shall be used so that a short-circuit in one circuit does not interrupt the supply to the adjacent luminaires within the fire compartment or the luminaires in other fire compartments.

No more than 20 luminaires with a total load not exceeding 60 percent of the nominal current of the overcurrent protective device shall be supplied from any final circuit.

Any circuit distribution, control or protective devices shall not impair the circuit integrity.

5.6.7.3 A safe value of minimum illuminance, response time and rated operation time is required to enable evacuation of a building. Where there are no national or local rules, illumination systems should comply with ISO 30061.

NOTE — Guidance on appropriate systems is given in Table 63.

5.6.7.4 Emergency lighting shall be wired in maintained or non-maintained mode. These modes may also be combined.

5.6.7.5 In the non-maintained mode, the power supply for the normal lighting shall be monitored at the final circuit for that area. If a loss of supply to the normal lighting in an area causes the normal lighting to fail, the emergency lighting shall be activated automatically. In all cases, arrangements shall be made to ensure that local emergency escape lighting will operate in the event of failure of normal supply to the corresponding local area.

5.6.7.6 Where maintained and non-maintained modes are used in combination, the changeover devices shall each have their own monitoring device and shall be able to be switched separately.

5.6.7.7 The maintained mode of emergency lighting may be simultaneously switched with normal lighting in locations which either;

— cannot be darkened when in use, or
— are not constantly occupied.

5.6.7.8 Control and bus systems for safety illumination shall be independent of control and bus systems for general illumination; coupling of both systems is permitted only with interfaces that ensure a decoupling/ isolation of both buses from each other. A failure in the control and bus system of the general illumination shall not influence the proper function of the safety illumination.

5.6.7.9 Changeover from normal to emergency mode shall start automatically if the supply voltage drops below 0.6 times the rated supply voltage for at least 0.5 s. It shall be restored if the supply voltage is greater than 0.85 times the rated supply voltage.

NOTES

1 The actual time for changeover shall be as per National Electric Code.

2 The level of changeover depends on the equipment used for safety services.

5.6.7.10 When the normal supply is restored to the distribution board or monitored circuit, the emergency lighting in non-maintained mode shall automatically switch off. Account shall be taken of the time necessary for the lamps in the normal lighting to return to normal luminance.

Account shall also be taken of rooms which had been intentionally 'blacked-out' before the supply was lost; in these cases, emergency lighting shall not switch off automatically.

5.6.7.11 In addition to central switching, it is permissible to monitor and control the supply to parts of a building which are occupied.

5.6.7.12 In emergency lighting systems the type of lamps shall be compatible with the changeover time in order to maintain the specified lighting level.

5.6.7.13 Control switches for emergency lighting shall be placed at a designated location and be arranged and installed in such a way that they cannot be operated by unauthorized persons.

5.6.7.14 The switched-on position of the emergency lighting shall be indicated at a convenient location for each source of supply.

5.6.7.15 Emergency lighting luminaires and associated circuit equipment shall be identified by a red label of at least 30 mm in diameter.

5.6.8 *Fire Protection Applications*

5.6.8.1 Wiring systems for fire detection and fire fighting power supplies shall be supplied by a separate circuit from the main incoming supply.

5.6.8.2 Preferential circuits, if any, shall be directly connected on the supply side of the isolating switch of the main distribution board.

NOTE — A private distribution network is regarded as equivalent to the distribution network of a public electricity company.

5.6.8.3 Alarm devices shall be clearly identified.

5.6.8.4 Except where there are applicable national rules, the minimum requirements for fire protection systems should be in accordance with Table 64.

6 VERIFICATION

6.1 Void

6.2 Initial Verification

NOTE — In Annex MM guidance on the application of the rules of **6** is given.

6.2.1 *General*

6.2.1.1 Every installation or change (namely addition or changes) to an existing installation shall be verified during erection, as far as reasonably practicable, and on completion, before being put into service by the user.

6.2.1.2 The information required by **5.1.4.5** and other information necessary for initial verification shall be made available to the person carrying out the initial verification.

6.2.1.3 Initial verification shall include comparison of the results with relevant criteria to confirm that the requirements this standard have been met.

6.2.1.4 Precautions shall be taken to ensure that the verification shall not cause danger to persons or livestock and shall not cause damage to property and equipment even if the circuit is defective.

6.2.1.5 For an addition or alteration to an existing installation, it shall be verified that the addition or alteration complies with this standard and does not impair the safety of the existing installation.

NOTE — For re-used equipment, *see* Annex MM.

6.2.1.6 The initial verification shall be made by a skilled person, competent in verification.

NOTE — For Requirements concerning qualifications for enterprises and persons, refer the relevant Central Electricity Regulations.

6.2.2 *Inspection*

6.2.2.1 Inspection shall precede testing and shall normally be done prior to energizing the installation.

6.2.2.2 The inspection shall be made to confirm that electrical equipment which is part of the fixed installation is:

a) in compliance with the safety requirements of the relevant equipment standards;

   NOTE — This may be ascertained by examination of the manufacturer's information, marking or certification.

b) correctly selected and erected according to this standard and to the manufacturer's instructions;

c) not visibly damaged so as to impair safety.

6.2.2.3 Inspection shall include at least the checking of the following, where relevant:

a) method of protection against electric shock (*see* **4.2**);

b) presence of fire barriers and other precautions against propagation of fire and protection against thermal effects (*see* **4.3** and **5.2.10**);

c) selection of conductors for current-carrying capacity and voltage drop (*see* **4.4**, **5.2.6** and **5.2.8**);

d) choice and setting of protective and monitoring devices (*see* **5.3**);
e) presence and correct location of suitable isolating and switching devices (*see* **5.3.6**);
f) selection of equipment and protective measures appropriate to external influences (*see* **4.3.2**, **5.1.2.2** and **5.2.5**);
g) neutral and protective conductors correctly identified (*see* **5.1.4.3**);
h) single-pole switching devices connected in the line conductors (*see* **5.3.7**);
j) presence of diagrams, warning notices or other similar information (*see* **5.1.4.5**);
k) identification of circuits, overcurrent protective devices, switches, terminals, etc (*see* **5.1.4**);
m) adequacy of connection of conductors (*see* **5.2.9**);
n) presence and adequacy of protective conductors, including main and supplementary equipotential bonding conductors (*see* **5.4**);
p) accessibility of equipment for convenience of operation, identification and maintenance (*see* **5.1.3** and **5.1.4**).

Inspection shall include all particular requirements for special installations or locations.

6.2.3 *Testing*

6.2.3.1 *General*

The test methods described in this clause are given as reference methods; other methods are not precluded, provided they give no less valid results.

Measuring instruments and monitoring equipment and methods shall be chosen in accordance with the relevant parts of IEC 61557. If other measuring equipment is used, it shall provide no less degree of performance and safety.

The following tests shall be carried out where relevant and should preferably be made in the following sequence:

a) continuity of conductors (*see* **6.2.3.2**);
b) insulation resistance of the electrical installation (*see* **6.2.3.3**);
c) protection by SELV, PELV or by electrical separation (*see* **6.2.3.4**);
d) floor and wall resistance/impedance (*see* **6.2.3.5**);
e) automatic disconnection of supply (*see* **6.2.3.6**);
f) additional protection (*see* **6.2.3.7**);
g) polarity test (*see* **6.2.3.8**);
h) test of the order of the phases (*see* **6.2.3.9**);
j) functional and operational tests (*see* **6.2.3.10**); and
k) voltage drop (*see* **6.2.3.11**).

In the event of any test indicating failure to comply, that test and any preceding test, the results of which may have been influenced by the fault indicated, shall be repeated after the fault has been rectified.

NOTE — When testing is in a potentially explosive atmosphere appropriate safety precautions in accordance with IS/IEC 60079-17 and IEC 61241-17 are necessary.

6.2.3.2 *Continuity of conductors*

An electrical continuity test shall be made on:

a) protective conductors, including main and supplementary equipotential bonding conductors, and
b) in the case of ring final circuits, live conductors.

NOTE — A ring final circuit is a final circuit arranged in a form of a ring connected to a single point of supply.

6.2.3.3 *Insulation resistance of the electrical installation*

The insulation resistance shall be measured between live conductors and the protective conductor connected to the earthing arrangement. For the purposes of this test, live conductors may be connected together.

Table 15 Minimum Values of Insulation Resistance
(*Clauses* 6.2.3.3 *and* 6.2.3.4)

Nominal Circuit Voltage V	**Test Voltage d.c.** V	**Insulation Resistance** MΩ
(1)	(2)	(3)
SELV and PELV	250	$\geq$ 0.5
Up to and including 500 V, including FELV	500	$\geq$ 1.0
Above 500 V	1 000	$\geq$ 1.0

The insulation resistance, measured with the test voltage indicated in Table 15, is satisfactory if each circuit, with the appliances disconnected, has an insulation resistance not less than the appropriate value given in Table 15.

Table 15 shall be applied for a verification of the insulation resistance between non-earthed protective conductors and earth.

Where surge protective devices (SPDs) or other equipment are likely to influence the verification test, or be damaged, such equipment shall be disconnected

before carrying out the insulation resistance test.

Where it is not reasonably practicable to disconnect such equipment (for example, in case of fixed socket-outlets incorporating an SPD), the test voltage for the particular circuit may be reduced to 250 V d.c., but the insulation resistance must have a value of at least 1 MΩ.

NOTES

1 For measurement purposes, the neutral conductor is disconnected from the protective conductor.

2 In TN-C systems, measurement is made between the live conductors and the PEN conductor.

3 In locations exposed to fire hazard, a measurement of the insulation resistance between the live conductors should be applied. In practice, it may be necessary to carry out this measurement during erection of the installation before the connection of the equipment.

4 Insulation resistance values are usually much higher than those of Table 65. When such values show evident differences, further investigation is needed to identify the reasons.

6.2.3.4 *Protection by SELV, PELV or by electrical separation*

The separation of circuits shall be in accordance with **6.2.3.4.1** in the case of protection by SELV, **6.2.3.4.2** in the case of protection by PELV and **6.2.3.4.3** in the case of protection by electrical separation.

The resistance value obtained in **6.2.3.4.1**, **6.2.3.4.2** and **6.2.3.4.3** shall be at least that of the circuit with the highest voltage present in accordance with Table 15.

6.2.3.4.1 *Protection by SELV*

The separation of the live parts from those of other circuits and from earth, according to **4.2.14**, shall be confirmed by a measurement of the insulation resistance. The resistance values obtained shall be in accordance with Table 15.

6.2.3.4.2 *Protection by PELV*

The separation of the live parts from other circuits, according to **4.2.13**, shall be confirmed by a measurement of the insulation resistance. The resistance values obtained shall be in accordance with Table 15.

6.2.3.4.3 *Protection by electrical separation*

The separation of the live parts from those of other circuits and from earth, according to **4.2.13**, shall be confirmed by a measurement of the insulation resistance. The resistance values obtained shall be in accordance with Table 15.

In case of electrical separation with more than one item of current-using equipment, either by measurement or by calculation, it shall be verified that in case of two coincidental faults with negligible impedance between different line conductors and either the protective bonding conductor or exposed-conductive-parts connected to it, at least one of the faulty circuits shall be disconnected. The disconnection time shall be in accordance with that for the protective measure automatic disconnection of supply in a TN-system.

6.2.3.5 *Insulation resistance/impedance of floors and walls*

When it is necessary to comply with the requirements of **MM-1**, at least three measurements shall be made in the same location, one of these measurements being approximately 1 m from any accessible extraneous-conductive-part in the location. The other two measurements shall be made at greater distances.

The measurement of resistance/impedance of insulating floors and walls is carried out with the system voltage to earth at nominal frequency.

The above series of measurements shall be repeated for each relevant surface of the location.

NOTE — In Annex KK, methods for measuring the insulating resistance/impedance of floors and walls are given as examples.

6.2.3.6 *Protection by automatic disconnection of the supply*

NOTE — Where RCDs are applied also for protection against fire, the verification of the conditions for protection by automatic

disconnection of the supply may be considered as covering the aspects of **4.3**.

6.2.3.6.1 *General*

The verification of the effectiveness of the measures for protection against indirect contact by automatic disconnection of supply is effected as follows:

a) *For TN systems*

Compliance with the rules of **4.2.11.4.4** and **4.2.11.3.2** shall be verified by:

1) measurement of the fault loop impedance (*see* **6.2.3.6.3**).

NOTE — When RCDs with $I_n \leq 500$ mA are used as disconnecting devices, measurement of the fault loop impedance is normally not necessary.

Alternatively, where the calculation of the fault loop impedance or of the resistance of the protective conductors are available, and where the arrangement of the installation permits the verification of the length and cross-sectional area of the conductors, the verification of the electrical continuity of the protective conductors (*see* **6.2.3.2**) is sufficient.

NOTE — Compliance may be verified by measurement of the resistance of protective conductors.

2) verification of the characteristics and/or the effectiveness of the associated protective device. This verification shall be made:

— for overcurrent protective devices, by visual inspection (that is, short time or instantaneous tripping setting for circuit-breakers, current rating and type for fuses);
— for RCDs, by visual inspection and test.

The effectiveness of automatic disconnection of supply by RCDs shall be verified using suitable test equipment according to IEC 61557-6 (*see* **6.2.3.1**) confirming that the relevant requirements of **4.2** are met.

It is recommended that the disconnecting times required by **4.2** be verified. However, the requirements for disconnecting times shall be verified in case of:

— re-used RCDs;
— additions or alterations to an existing installation where existing RCDs are also to be used as disconnecting devices for such additions or alterations.

NOTE — Where the effectiveness of the protective measure has been confirmed at a point located downstream of an RCD, the protection of the installation downstream from this point may be proved by confirmation of the continuity of the protective conductors.

In addition, it shall be confirmed by mutual agreement between the contractor and the electricity supplier that the requirement of **4.2.11.4.1** is complied with.

b) *For TT systems*

Compliance with the rules of **4.2.11.5.3** shall be verified by:

1) measurement of the resistance R_A of the earth electrode for exposed-conductive-parts of the installation (*see* **6.2.3.6.2**);

NOTE — Where the measurement of R_A is not possible, it may be possible to replace it by the measure of the fault loop impedance as in **6.2.3.6.1** (a) (1).

2) verification of the characteristics and/or effectiveness of the associated protective device. This verification shall be made:

— for overcurrent protective devices, by visual inspection (that is, short time or instantaneous tripping setting for circuit-breakers, current rating and type for fuses);
— for RCDs, by visual inspection and by test.

The effectiveness of automatic disconnection of supply by RCDs shall be verified using suitable test equipment according to IEC 61557-6 (*see* **6.2.3.1**) confirming that the relevant requirements of **4.2** are met.

It is recommended that the disconnecting times required by **4.2** be verified. However, the requirements for disconnecting times shall be verified in case of:

— re-used RCDs;
— additions or alterations to an existing installation where existing RCDs are also to be used as disconnecting devices for such additions or alterations.

NOTE — Where the effectiveness of the protective measure has been confirmed at a point located downstream of an RCD, the protection of the installation downstream from this point may be proved by confirmation of the continuity of the protective conductors.

c) *For IT systems*

Compliance with the rules of **4.2.11.6.2** shall be verified by calculation or measurement of the current I_d in case of a first fault at the line conductor or at the neutral.

NOTE — The measurement is made only if the calculation is not possible, because all the parameters are not known. Precautions are to be taken while making the measurement in order to avoid the danger due to a double fault.

Where conditions that are similar to conditions of TT systems occur, in the event of a second fault in another circuit [*see* **4.2.11.6.4** (a)], verification is made as for TT systems [*see* **4.2.11.6.4** (b)].

Where conditions that are similar to conditions of TN systems occur, in the event of a second fault in another circuit [*see* **4.2.11.6.4**(b)], verification is made as for TN systems [*see* **4.2.11.6.4**(a)].

NOTE — During the measurement of the fault loop impedance, it is necessary to establish a connection of negligible impedance between the neutral point of the system and the protective conductor preferably at the origin of installation.

6.2.3.6.2 *Measurement of the resistance of the earth electrode*

Measurement of the resistance of an earth electrode, where prescribed (*see* **4.2.11.5.3**, for TT systems, **4.2.11.4.1** for TN systems, and **4.2.11.6.2** for IT systems), is made by an appropriate method.

NOTES

1 Annex LL, Method LL1, gives, as an example, a description of a method of measurement using two auxiliary earth electrodes and the conditions to be fulfilled.

2 Where the location of the installation (for example, in towns) is such that it is not possible in practice to provide the two auxiliary earth electrodes, measurement of the fault loop impedance according to **6.1.3.6.3**, or Annex LL, Methods LL2 and LL3, will give an excess value.

6.2.3.6.3 *Measurement of the fault loop impedance*

An electrical continuity test shall be made according to **6.2.3.2** before carrying out the fault loop impedance measurement.

The measured fault loop impedance shall comply with **4.2.11.4.4** for TN systems and with **4.2.11.6.4** for IT systems.

Where the requirements of this subclause are not

satisfied or in case of doubt and where supplementary equipotential bonding according to **4.2.15.2** is applied, the effectiveness of that bonding shall be checked according to **4.2.15.2.2**.

6.2.3.7 *Additional protection*

The verification of the effectiveness of the measures applied for additional protection is fulfilled by visual inspection and test.

Where RCDs are required for additional protection, the effectiveness of automatic disconnection of supply by RCDs shall be verified using suitable test equipment according to IEC 61557-6 (*see* **6.2.3. 1**) confirming that the relevant requirements of **4.2** are met.

NOTE — Where an RCD is provided for fault protection and for additional protection, it should be tested according to the relevant most onerous requirements of **4.2.**

Where the rules forbid the installation of single-pole switching devices in the neutral conductor, a test shall be made to verify that all such devices are connected in the line conductor(s) only.

6.2.3.8 *Check of phase sequence*

In case of multiphase circuits, it shall be verified that the phase sequence is maintained.

6.2.3.9 *Functional tests*

Assemblies, such as switchgear and controlgear assemblies, drives, controls and interlocks, shall be subjected to a test of their function to verify that they are properly mounted, adjusted and installed in accordance with the relevant requirements of this standard.

Protective devices shall be submitted to a test of their function, as necessary, to check that they are properly installed and adjusted.

NOTE — This functional test does not replace the functional test indicated by the relevant standards.

6.2.3.10 *Verification of voltage drop*

Where required to verify compliance with **5.2.8**, the following options may be used:

a) the voltage drop may be evaluated by measuring the circuit impedance;
b) the voltage drop may be evaluated by using diagrams similar to the one shown as an example in Annex NN.

6.2.4 *Reporting for Initial Verification*

6.2.4.1 Upon completion of the verification of a new installation or additions or alterations to an existing installation, an initial report shall be provided. Such documentation shall include details of the extent of the installation covered by the report, together with a record of the inspection and the results of testing.

Any defects or omissions revealed during verification of the work shall be made good before the contractor declares that the installation complies with this standard.

6.2.4.2 In the case of initial verification of alterations or additions of existing installations, the report may contain recommendations for repairs and improvements, as may be appropriate.

6.2.4.3 The initial report shall include:

a) records of inspections; and
b) records of circuits tested and test results.

The records of circuit details and test results shall identify every circuit, including its related protective device(s), and shall record the results of the appropriate tests and measurements.

6.2.4.4 The person or persons responsible for the safety, construction and verification of the installation, shall give the report, which takes account of their respective responsibilities, to the person ordering the work, together with the records mentioned in **6.2.4.3**.

NOTE — The initial report of the electrical installation should make a recommendation for a period between initial verification and the first periodic verification.

6.2.4.5 Reports shall be compiled and signed or otherwise authenticated by a person or persons competent in verification.

NOTE — Annexes QQ, RR and SS give model forms of schedules that might be used for the description and for initial, and also periodic, verification of installations, particularly suitable for domestic installations.

6.3 Periodic Verification

6.3.1 *General*

6.3.1.1 Where required, periodic verification of every electrical installation shall be carried out in accordance with **6.3.1.2** to **6.3.1.6**.

Wherever possible, the records and recommendations of previous periodic verifications shall be taken into account.

6.3.1.2 Periodic inspection comprising a detailed examination of the installation shall be carried out without dismantling, or with partial dismantling, as required, supplemented by appropriate tests from **6.2**, including verification, to show that the requirements for disconnecting times as set out in **4.2** for RCDs are complied with, and by measurements, to provide for:

a) safety of persons and livestock against the effects of electric shock and burn,
b) protection against damage to property by fire

and heat arising from an installation defect,

c) confirmation that the installation is not damaged or deteriorated so as to impair safety, and

d) the identification of installation defects and departures from the requirements of this standard that may give rise to danger.

6.3.1.3 Precautions shall be taken to ensure that the periodic verification shall not cause danger to persons or livestock and shall not cause damage to property and equipment even if the circuit is defective.

Measuring instruments and monitoring equipment and methods shall be chosen in accordance with relevant parts of IEC 61557. If other measuring equipment is used, it shall provide no less degree of performance and safety.

6.3.1.4 The extent and results of the periodic verification of an installation, or any part of an installation, shall be recorded.

6.3.1.5 Any damage, deterioration, defects or dangerous condition shall be recorded. Furthermore, significant limitations of the periodic verification in accordance with this standard and their reasons shall be recorded.

6.3.1.6 The verification shall be made by a skilled person, competent in verification.

NOTE — Requirements concerning qualifications for enterprises and persons are a matter for national consideration.

6.3.2 *Frequency of Periodic Verification*

6.3.2.1 The frequency of periodic verification of an installation shall be determined having regard to the type of installation and equipment, its use and operation, the frequency and quality of maintenance and the external influences to which it is subjected.

NOTES

1 The maximum interval between periodic verifications may be recommended for guidance in the Regulatory Measures Relating to Electrical Safety and Supply under the Electricity Act, 2003.

2 The periodic report should recommend to the person carrying out the periodic verification the interval to the next periodic verification.

3 The interval may be, for instance some years (for example, 4 years), with the exception of the following cases where a higher risk may exist and shorter periods may be required:

a) working places or locations where risks of electric shock, fire or explosion exist due to degradation;

b) working places or locations where both high and low voltage installations exist;

c) communal facilities;

d) construction sites; and

e) safety installations (for example emergency luminaires).

For residential dwellings, occupied by the owner himself, longer periods (for example, 10 years) between initial inspections and first periodical inspection may be appropriate. The periodical interval however, may be shorter (for example, 5 years) after a life period of 20 years from initial erection. It is the primary responsibility of the owner to carry out verification (inspection and testing) of the electrical installation in residential dwelling at the time of renting to a tenant or at the time when the tenant is changed and report of inspection and testing of the electrical installation in the building premises should be attached with the rent agreement document. When occupancy of a dwelling has changed (for example, from residential to office etc), a verification of the electrical installation is strongly recommended.

The results and recommendations of the previous reports, where available, shall be taken into account.

NOTE — Where no previous report is available, further investigation is necessary.

6.3.2.2 In the case of an installation under an effective management system for preventive maintenance in normal use, periodic verification may be replaced by an adequate regime of continuous monitoring and maintenance of the installation and all its constituent equipment by skilled persons. Appropriate records shall be kept.

6.3.3 *Reporting for Periodic Verification*

6.3.3.1 Upon completion of the periodic verification of an existing installation, a periodic report shall be provided. Such documentation shall include details of those parts of the installation and limitations of the verification covered by the report, together with a record of the inspection, including any deficiencies listed under **6.3.1.5**, and the results of testing. The periodic report may contain recommendations for repairs and improvements, such as upgrading the installation to comply with the current standard, as may be appropriate.

The periodic report shall be given by the person responsible for carrying out the verification, or a person authorized to act on their behalf, to the person ordering the verification.

6.3.3.2 The records of test results shall record the results of the appropriate tests detailed in **6.3**. Reports shall be compiled and signed or otherwise authenticated by a competent person or persons.

ANNEX A

(*Clause* 4.2.13.2)

(*Normative*)

PROVISIONS FOR BASIC PROTECTION

NOTE — Provisions for basic protection provide protection under normal conditions and are applied where specified as a part of the chosen protective measure.

A-1 BASIC INSULATION OF LIVE PARTS

NOTE — The insulation is intended to prevent contact with live parts.

Live parts shall be completely covered with insulation which can only be removed by destruction.

For equipment, the insulation shall comply with the relevant standard for the electrical equipment.

A-2 BARRIERS OR ENCLOSURES

NOTE — Barriers or enclosures are intended to prevent contact with live parts.

A-2.1 Live parts shall be inside enclosures or behind barriers providing at least the degree of protection IPXXB or IP2X except that, where larger openings occur during the replacement of parts, such as certain lampholders or fuses, or where larger openings are necessary to allow the proper functioning of equipment according to the relevant requirements for the equipment:

a) suitable precautions shall be taken to prevent persons or livestock from unintentionally touching live parts;
b) it shall be ensured, as far as practicable, that persons will be aware that live parts can be touched through the opening and should not be touched intentionally; and
c) the opening shall be as small as is consistent with the requirement for proper functioning and for replacement of a part.

A-2.2 Horizontal top surfaces of barriers or enclosures which are readily accessible shall provide a degree of protection of at least IPXXD or IP4X.

A-2.3 Barriers and enclosures shall be firmly secured in place and have sufficient stability and durability to maintain the required degrees of protection and appropriate separation from live parts in the known conditions of normal service, taking account of relevant external influences.

A-2.4 Where it is necessary to remove barriers or open enclosures or to remove parts of enclosures, this shall be possible only;

a) by the use of a key or tool, or
b) after disconnection of the supply to live parts against which the barriers or enclosures afford protection, restoration of the supply being possible only after replacement or reclosure of the barriers or enclosures, or
c) where an intermediate barrier providing a degree of protection of at least IPXXB or IP2X prevents contact with live parts, by the use of a key or tool to remove the intermediate barrier.

A-2.5 If, behind a barrier or in an enclosure, items of equipment are installed which may retain dangerous electrical charges after they have been switched off (capacitors, etc), a warning label is required. Small capacitors such as those used for arc extinction, for delaying the response of relays, etc shall not be considered dangerous.

NOTE — Unintentional contact is not considered dangerous if the voltage resulting from static charges fall below 120 V d.c. in less than 5 s after disconnection from the power supply.

ANNEX B

(*Clause* 4.5.3.2.2.1)
(*Normative*)

OBSTACLES AND PLACING OUT OF REACH

B-1 APPLICATION

The protective measures of obstacles and placing out of reach provide basic protection only.

They are for application in installations with or without fault protection that are controlled or supervised by skilled or instructed persons.

The conditions of supervision under which, the basic protective provisions of this Annex may be applied, as part of the protective measure are given in **4.2.6**.

B-2 OBSTACLES

NOTE — Obstacles are intended to prevent unintentional contact with live parts but not intentional contact by deliberate circumvention of the obstacle.

B-2.1 Obstacles shall prevent:

a) unintentional bodily approach to live parts, and
b) unintentional contact with live parts during the operation of live equipment in normal service.

B-2.2 Obstacles may be removed without using a key or tool but shall be secured so as to prevent unintentional removal.

B-3 PLACING OUT OF REACH

NOTE — Protection by placing out of reach is intended only to prevent unintentional contact with live parts.

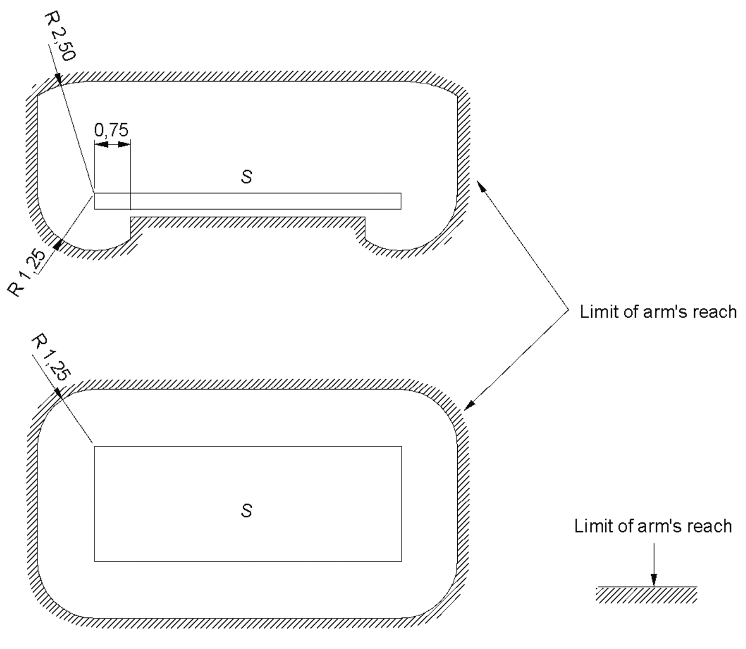
B-3.1 Simultaneously accessible parts at different potentials shall not be within arm's reach.

NOTE — Two parts are deemed to be simultaneously accessible if they are not more than 2.50 m apart (*see* Fig. 62).

B-3.2 If a normally occupied position is restricted in the horizontal direction by an obstacle (for example, handrail, mesh screen etc) affording a degree of protection less than IPXXB or IP2X, arm's reach shall extend from that obstacle. In the overhead direction, arm's reach is 2.50 m from the surface, *S*, not taking into account any intermediate obstacle providing a degree of protection less than IPXXB.

NOTE — The values of arm's reach apply to contact directly with bare hands without assistance (for example, tools or ladder).

B-3.3 In places where bulky or long conductive objects are normally handled, the distances required by **B-3.1** and **B-3.2** shall be increased, taking account of the relevant dimensions of those objects.



S surface expected to be occupied by persons

All dimensions in metres.

FIG. 62 ZONE OF ARM'S REACH

ANNEX C

(*Clause* 4.2.13.1.3)

(*Normative*)

PROTECTIVE MEASURES FOR APPLICATION ONLY WHEN THE INSTALLATION IS CONTROLLED OR UNDER THE SUPERVISION OF SKILLED OR INSTRUCTED PERSONS

NOTE — The conditions of supervision under which the fault protective provisions (protection against indirect contact) of Annex C may be applied as part of the protective measure are given in **4.2.7**.

C-1 NON-CONDUCTING LOCATION

NOTE — This protective measure is intended to prevent simultaneous contact with parts which may be at different potential through failure of the basic insulation of live parts.

C-1.1 All electrical equipment shall comply with one of the provisions for basic protection described in Annex A.

C-1.2 Exposed-conductive-parts shall be arranged so that under ordinary circumstances persons will not come into simultaneous contact with;

a) two exposed-conductive-parts, or
b) an exposed-conductive-part and any extraneous-conductive-part,

if these parts are liable to be at different potential through failure of the basic insulation of live parts.

C-1.3 In a non-conducting location there shall be no protective conductor.

C-1.4 The requirement of **C-1.2** is fulfilled if the location has an insulating floor and walls and one or more of the following arrangements applies:

a) Relative spacing of exposed-conductive-parts and of extraneous-conductive-parts as well as spacing of exposed-conductive-parts.

   This spacing is sufficient if the distance between two parts is not less than 2.50 m; this distance may be reduced to 1.25 m outside the zone of arm's reach.

b) Interposition of effective obstacles between exposed-conductive-parts and extraneous-conductive-parts.

   Such obstacles are sufficiently effective if they extend the distances to be surmounted to the values stated in point **C-1.4** (a). They shall not be connected to earth or to exposed-conductive-parts; as far as possible they shall be of insulating material.

c) Insulation or insulating arrangements of extraneous-conductive-parts.

The insulation shall be of sufficient mechanical strength and be able to withstand a test voltage of at least 2 000 V. Leakage current shall not exceed 1 mA in normal conditions of use.

C-1.5 The resistance of insulating floors and walls at every point of measurement under the conditions specified in **6** shall be not less than:

a) 50 kΩ, where the nominal voltage of the installation does not exceed 500 V, or
b) 100 kΩ, where the nominal voltage of the installation exceeds 500 V.

NOTE — If at any point the resistance is less than the specified value, the floors and walls are deemed to be extraneous-conductive-parts for the purposes of protection against shock.

C-1.6 The arrangements made shall be permanent and it shall not be possible to make them ineffective. They shall also ensure protection where the use of mobile or portable equipment is envisaged.

NOTES

1 Attention is drawn to the risk that, where electrical installations are not under effective supervision, further conductive parts may be introduced at a later date (for example, mobile or portable Class I equipment or extraneous-conductive-parts such as metallic water pipes), which may invalidate compliance with **C-1.6**.

2 It is essential to ensure that the insulation of floor and walls cannot be affected by humidity.

C-1.7 Precautions shall be taken to ensure that extraneous-conductive-parts cannot cause a potential to appear externally to the location concerned.

C-2 PROTECTION BY EARTH-FREE LOCAL EQUIPOTENTIAL BONDING

NOTE — Earth-free local equipotential bonding is intended to prevent the appearance of a dangerous touch voltage.

C-2.1 All electrical equipment shall comply with one of the provisions for basic protection (protection against direct contact) described in Annex A.

C-2.2 Equipotential bonding conductors shall interconnect all simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts.

C-2.3 The local equipotential bonding system shall not be in electrical contact with earth directly, nor through exposed-conductive-parts, nor through extraneous-conductive-parts.

NOTE — Where this requirement cannot be fulfilled, protection by automatic disconnection of supply is applicable (*see* **4.2.11**).

C-2.4 Precautions shall be taken to ensure that persons entering the equipotential location cannot be exposed to a dangerous potential difference, in particular, where a conductive floor insulated from earth is connected to the earth-free equipotential bonding system.

C-3 ELECTRICAL SEPARATION FOR THE SUPPLY OF MORE THAN ONE ITEM OF CURRENT-USING EQUIPMENT

NOTE — Electrical separation of an individual circuit is intended to prevent shock currents through contact with exposed-conductive-parts that may be energized by a fault in the basic insulation of the circuit.

C-3.1 All electrical equipment shall comply with one of the provisions for basic protection described in Annex A.

C-3.2 Protection by electrical separation for the supply of more than one item of apparatus shall be ensured by compliance with all the requirements of **4.2.13** except **4.2.13.1.2**, and with the following requirements.

C-3.3 Precautions shall be taken to protect the separated circuit from damage and insulation failure.

C-3.4 The exposed-conductive-parts of the separated circuit shall be connected together by insulated, non-earthed equipotential bonding conductors. Such conductors shall not be connected to the protective conductors or exposed-conductive-parts of other circuits or to any extraneous-conductive-parts (*see* Note under **4.2.13.3.6**).

C-3.5 All socket-outlets shall be provided with protective contacts which shall be connected to the equipotential bonding system provided in accordance with **C-3.4**.

C-3.6 Except where supplying equipment with double or reinforced insulation, all flexible cables shall embody a protective conductor for use as an equipotential bonding conductor in accordance with **C-3.4**.

C-3.7 It shall be ensured that if two faults affecting two exposed-conductive-parts occur and these are fed by conductors of different polarity, a protective device shall disconnect the supply in a disconnecting time conforming with Table 1.

C-3.8 It is recommended that the product of the nominal voltage of the circuit in volts and length, in metres, of the wiring system should not exceed 100 000 V/m, and that the length of the wiring system should not exceed 500 m.

ANNEX D

(*Clause* 4.4)

(*Normative*)

PROTECTION OF CONDUCTORS IN PARALLEL AGAINST OVERCURRENT

D-1 INTRODUCTION

Overcurrent protection for conductors connected in parallel should provide adequate protection for all of the parallel conductors. For two conductors of the same cross-sectional area, conductor material length and method of installation arranged to carry substantially equal currents, the requirements for overcurrent protection are straightforward. For more complex conductor arrangements, detailed consideration should be given to unequal current sharing between conductors and multiple fault current paths. This annex gives guidance on the necessary considerations.

NOTE — A more detailed method for calculating the current between parallel conductors is given in IEC 60287-1-3.

D-2 OVERLOAD PROTECTION OF CONDUCTORS IN PARALLEL

When an overload occurs in a circuit containing parallel conductors of multicore cables, the current in each conductor will increase by the same proportion. Provided that the current is shared equally between the parallel conductors, a single protective device can be used to protect all the conductors. The current-carrying capacity (I_z) of the parallel conductors is the sum of the current-carrying capacity of each conductor, with the appropriate grouping and other factors applied.

The current sharing between parallel cables is a function of the impedance of the cables. For large, single-core cables the reactive component of the impedance is greater than the resistive component and will have a

significant effect on the current sharing. The reactive component is influenced by the relative physical position of each cable. If, for example, a circuit consists of two large cables per phase, having the same length, construction and cross-sectional area and arranged in parallel but with adverse relative positioning (that is, cables of the same phase bunched together) the current sharing may be 70 percent/30 percent rather than 50 percent/50 percent).

Where the difference in impedance between parallel conductors causes unequal current sharing, for example greater than 10 percent difference, the design current and requirements for overload protection for each conductor should be considered individually.

The design current for each conductor can be calculated from the total load and the impedance of each conductor.

For a total of *m* conductors in parallel, the design current I_{Bk} for conductor *k* is given by:

$$I_{Bk} = \frac{I_B}{\left(\frac{Z_k}{Z_1}+\frac{Z_k}{Z_2}+\cdots+\frac{Z_k}{Z_{k-1}}+\frac{Z_k}{Z_k}+\frac{Z_k}{Z_{k+1}}+\cdots+\frac{Z_k}{Z_m}\right)} \quad \text{... (3)}$$

where

I_B = the current for which the circuit is designed;

I_{Bk} = the design current for conductor *k*;

Z_k = the impedance of conductor *k*; and

Z_1 and Z_m = the impedances of conductors 1 and *m*, respectively.

In case of parallel conductors up to and including 120 mm^2 the design current I_{Bk} for conductor *k* is given by:

$$I_{Bk} = I_B \frac{S_k}{\left(S_1 + S_2 + ... + S_m\right)} \quad \text{... (4)}$$

where

S_k = the cross-sectional area of conductor *k*; and

$S_1 \ldots S_m$ = the cross-sectional area of the conductors.

In the case of single-core cables, the impedance is a function of the relative positions of the cables as well as the design of the cable, for example armoured or unarmoured. Methods for calculating the impedance are given in IEC 60287-1-3. It is recommended that current sharing between parallel cables is verified by measurement.

The design current I_{Bk} is used in place of I_B for Equation (1) of **4.4.4.1** as follows:

$$I_{Bk} \le I_n \le I_{zk} \quad \text{.... (5)}$$

The value used for I_z in **4.4.4.1**, Equations (1) and (2), is either the continuous current-carrying capacity of each conductor, I_{zk}, if an overload protective device is provided for each conductor (*see* Fig. 63) hence:

$$I_{Bk} \le I_{nk} \le I_{zk} \quad \text{....(6)}$$

or

the sum of the current-carrying capacities of all the conductors, $\sum I_{zk}$, if a single overload protective device is provided for the conductors in parallel (*see* Fig. 64) hence:

$$I_B \le I_n \le I_{zk} \quad \text{....(7)}$$

where

I_{nk} = the nominal current of the protective device for conductor *k*;

I_{zk} = the continuous current-carrying capacity of conductor *k*;

I_n = the rated current of the protective device; and

I_{zk} = the sum of the continuous current-carrying capacities of the m conductors in parallel.

NOTE — For busbar systems, information should be obtained either from the manufacturer or from IEC 60439-2.

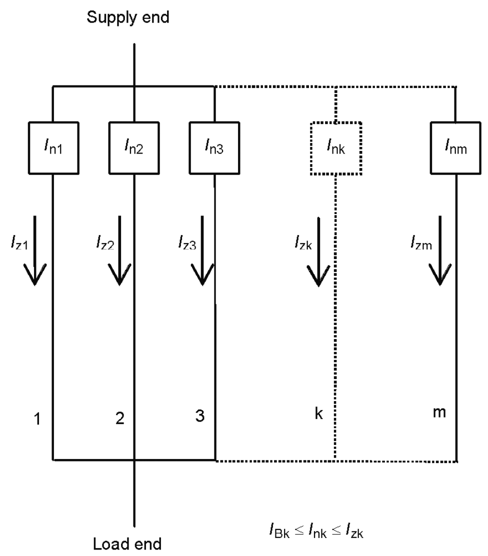


FIG. 63 CIRCUIT IN WHICH AN OVERLOAD PROTECTIVE DEVICE IS PROVIDED FOR EACH OF THEM CONDUCTORS IN PARALLEL

D-3 SHORT-CIRCUIT PROTECTION OF CONDUCTORS IN PARALLEL

Where conductors are connected in parallel, the effect of a short-circuit within the parallel section should be considered with respect to the protective device arrangement.

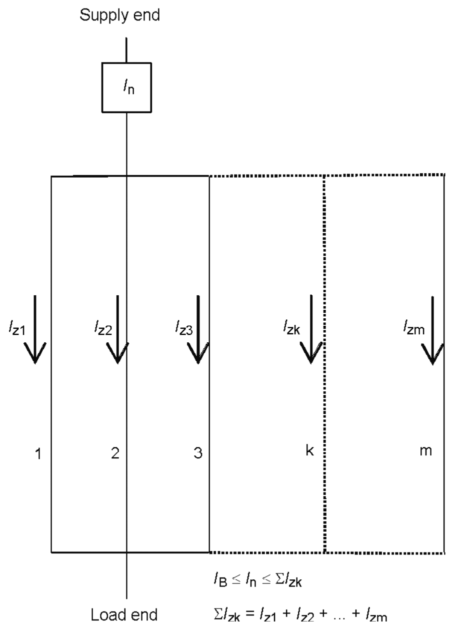


FIG. 64 CIRCUIT IN WHICH A SINGLE OVERLOAD PROTECTIVE DEVICE IS PROVIDED FOR THE *m* CONDUCTORS IN PARALLEL

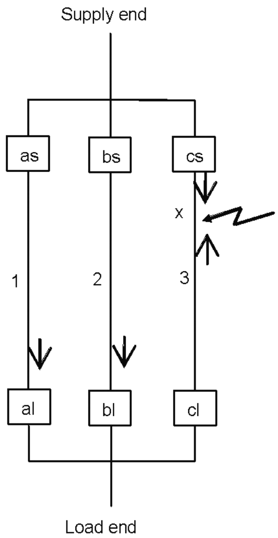


FIG. 65 CURRENT FLOW AT THE BEGINNING OF THE FAULT

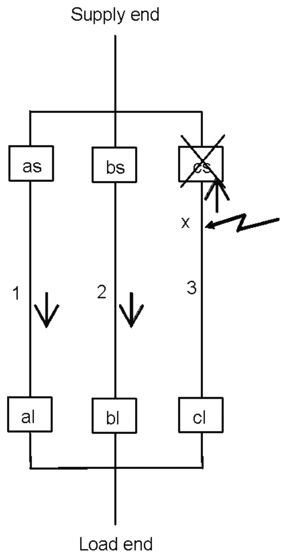


FIG. 66 CURRENT FLOW AFTER OPERATION OF THE PROTECTIVE DEVICES

Individual conductors in a parallel arrangement may not be effectively protected when using single protective devices, thus consideration should be given to providing other protective arrangements. These could include individual protective devices for each conductor, protective devices at the supply and load ends of the parallel conductors, and linked protective devices at the supply end. Determination of the particular protection arrangement will be dependent on the likelihood of fault conditions.

Where conductors are connected in parallel, then multiple fault current paths can occur resulting in continued energizing of one side of the fault location. This could be addressed by providing short-circuit protection at both the supply (*s)* and load (*l)* end of each parallel conductor. This situation is illustrated in Fig. 65 and Fig. 66.

Figure 65 shows that, if a fault occurs in parallel conductor 3 at point *x*, the fault current will flow in conductors 1, 2 and 3. The magnitude of the fault current and the proportion of the fault current which flows through protective devices cs and cl will depend on the location of the fault. In this example it has been assumed that the highest proportion of the fault current will flow through protective devices. Figure 66 shows that, once cs has operated, current will still flow to the fault at x via conductors 1 and 2. Because conductors 1 and 2 are in parallel, the divided current through protective devices as and bs may not be sufficient for them to operate in the required time. If this is the case, the protective device cl is necessary. It should be noted that the current flowing through cl will be less than the current which caused cs to operate. If the fault was close enough to cl then cl would operate first. The same situation would exist if a fault occurred in conductors 1 or 2, hence the protective devices al and bl will be required.

The method of providing protective devices at both ends has two disadvantages compared to the method of providing protective devices at the supply ends only. Firstly, if a fault of x is cleared by the operation of cs and cl, then the circuit will continue to operate with the load being carried by conductors 1 and 2. Hence, the fault and subsequent overloading of conductors 1 and 2 may not be detected, depending on the fault

impedance. Secondly, the fault at x may burn open-circuit at the cl side, leaving one side of the fault live and undetected.

An alternative to the six protective devices would be to provide linked protective device(s) at the supply end (*see* Fig. 67). This would prevent the continued operation of the circuit under fault conditions.

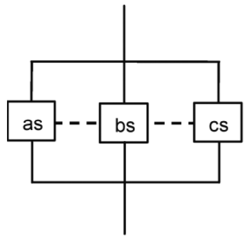


FIG. 67 ILLUSTRATION OF LINKED PROTECTIVE DEVICE

ANNEX E

(*Clause* 4.4)

(*Normative*)

CONDITIONS 1 AND 2 OF 4.4.4.1

$$I_B \leq I_n \leq I_Z \quad ....(8)$$

$$I_2 \leq 1.45 \times I_Z \quad ....(9)$$

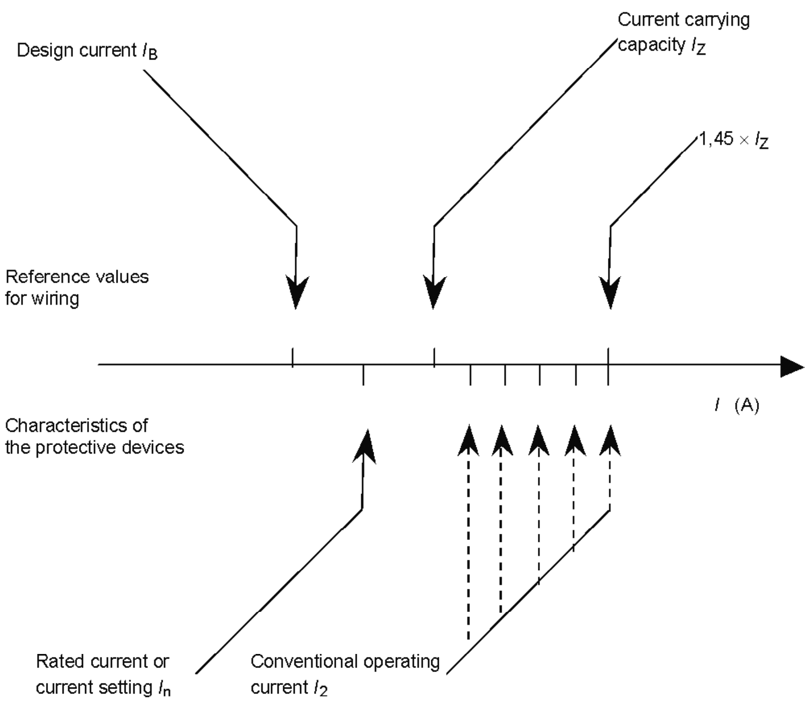


FIG. 68 ILLUSTRATION OF CONDITIONS 1 AND 2 OF **4.4.4.1**

ANNEX F

(*Clause* 4.4)
(*Normative*)

POSITION OR OMISSION OF DEVICES FOR OVERLOAD PROTECTION

F-1 GENERAL

Devices for overload protection and devices for short-circuit protection have to be installed for each circuit. These protective devices generally need to be placed at the origin of each circuit. For some applications, one of the devices for overload protection or for short-circuit protection may not follow this general requirement, provided the other protection remains operative.

F-2 CASES WHERE OVERLOAD PROTECTION NEED NOT BE PLACED AT THE ORIGIN OF THE BRANCH CIRCUIT

a) With reference to **4.4.4.2.2**(a) and Fig. 69, an overload protective device P_2 may be moved from the origin (*O*) of the branch circuit (*B*) provided that there is no other connection or socket-outlet on the supply side of P_2, the protective device of this branch circuit, and in accordance with the requirements of **4.4.4.2.2**(a), short-circuit protection for this part of the branch circuit is provided.

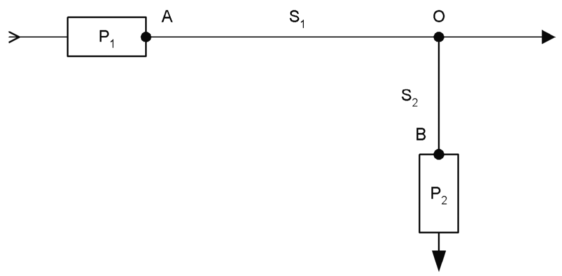


FIG. 69 OVERLOAD PROTECTIVE DEVICE (P_2) NOT AT THE ORIGIN OF BRANCH CIRCUIT (*B*) [*see* **4.4.4.2.2**(a)]

The overload protective device is to protect the wiring system. Only current-using equipment may generate overload; therefore the overload protective device may be moved along the run of the branch circuit to any place provided short-circuit protection of the branch circuit remains operational.

b) With reference to **4.4.4.2.2**(b) and Fig. 70, an overload protective device P_2 may be moved up to 3 m from the origin (*O*) of the branch circuit (*B)* provided that there is no other connection or socket-outlet on this length of the branch circuit, and in accordance with the requirements of **4.4.4.2.2** (b) its length does not exceed 3 m, and the risk of short-circuit, fire and danger to person is reduced to a minimum for this length.

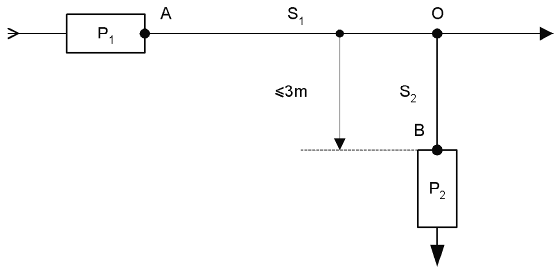


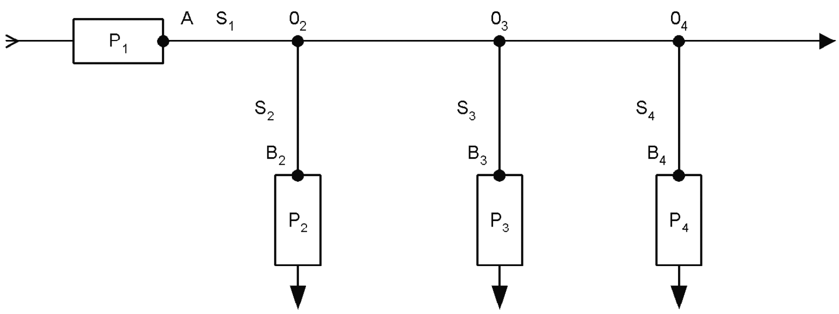
FIG. 70 OVERLOAD PROTECTIVE DEVICE (P_2) INSTALLED WITHIN 3 m OF THE ORIGIN OF THE BRANCH CIRCUIT (*B*) [*see* **4.4.4.2.2**(b)]

It is accepted that for a length of 3 m, the branch circuit is not protected against short-circuit, but precautions have to be taken to ensure safety [*see* **4.4.4.2.2**(b)]. In addition it may be possible that the short-circuit protection of the supply circuit also provides short-circuit protection to the branch circuit up to the point where P_2 is installed (*see* Annex G).

F-3 CASES WHERE OVERLOAD PROTECTION MAY BE OMITTED

a) With reference to **4.4.4.3.1** and Fig.71, omission of overload protection is permitted provided that there is no other connection or socket-outlet on the supply side of the protective device of this branch circuit, and that one of the following applies:
   - branch circuit S_2 is protected against overload by P_1 [*see* **4.4.4.3.1**(a)]; or
   - branch circuit S_3 is not likely to carry overload [*see* **4.4.4.3.1**(b)]; or
   - BRANCH circuit S_4 is for telecommunication, control, signalling and the like [*see* **4.4.4.3.1**(d)].

With reference to **4.4.4.3.2.1** and Fig. 72, additional requirements of **F-2** and **F-3** (a), only applicable to IT systems, are required by **4.4.4.3.2.1**. Overload protection may be omitted provided that there is no other connection or socket-outlet on the supply side of P_2, the protective device of this branch circuit, and that one of the following applies:



NOTE — P_2, P_3 and P_4 are the short-circuit protective devices for branch circuits S_2, S_3 and S_4 respectively.

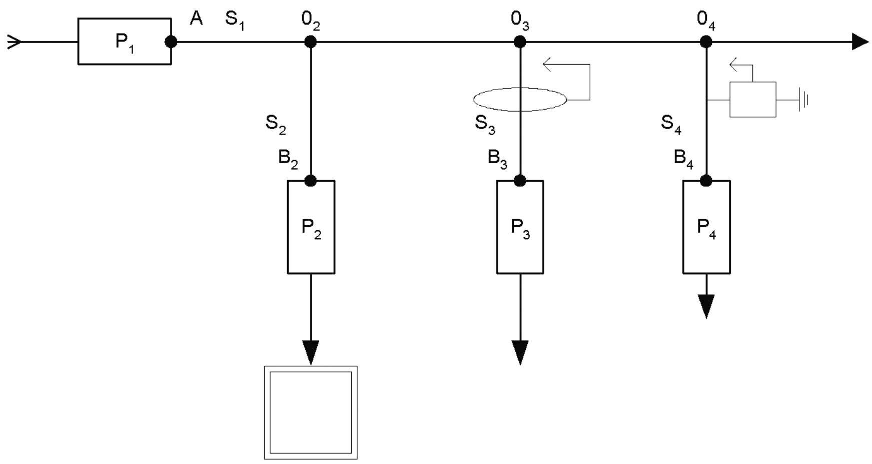
FIG. 71 ILLUSTRATION OF CASES WHERE OVERLOAD PROTECTION MAY BE OMITTED
[*see* **4.4.4.3.1**(a), (b) and (d)]

— branch circuit S_2 employs the protective measures described in **4.2.12** and consists of class II equipment; or

— branch circuit S_3 is protected by an RCD that will operate immediately on the occurrence of a second fault; or

— branch circuit S_4 is equipped with an insulation monitoring device that causes the disconnection of the circuit when the first fault occurs or provides an alarm signal indicating the presence of a fault.

In an IT system, consideration needs to be given to the possible occurrence of two separate insulation faults affecting different circuits. In most cases, the occurrence of two separate faults results in a short-circuit situation. However, the fault impedance, lengths and cross-sectional areas of both circuits involved may be unknown. As a consequence, the possible occurrence of two separate insulation faults may result in an overload situation for at least one of the protective devices.



NOTE — P_2, P_3 and P_4 are the short-circuit protective devices for branch circuits S_2, S_3 and S_4, respectively.

FIG. 72 ILLUSTRATION OF CASES WHERE OVERLOAD PROTECTION MAY BE OMITTED IN AN IT SYSTEM

ANNEX G

(*Clauses* 4.4.4.4.2 *and* 4.4.5.2.2)
(*Normative*)

POSITION OR OMISSION OF DEVICES FOR SHORT-CIRCUIT PROTECTION

G-1 GENERAL

Devices for overload protection and devices for short-circuit protection have to be installed for each circuit. These protective devices generally need to be placed at the origin of each circuit.

For some applications, one of the devices for overload protection or for short-circuit protection may not follow this general requirement, provided the other protection remains operative.

G-2 CASES WHERE SHORT-CIRCUIT PROTECTION DOES NOT NEED TO BE PLACED AT THE ORIGIN OF BRANCH CIRCUIT

a) With reference to **4.4.5.2.1** and Fig. 73, short-circuit protective device may be moved up to 3 m from the origin (*O*) of the branch circuit (S_2) provided that there is no other connection or socket-outlet on this length of the branch circuit, and in the case of **4.4.5.2.1** the risk of short-circuit, fire and danger to persons is reduced to a minimum for this length.

The 3 m length of conductor in the branch circuit is not protected against short-circuit, but the short-circuit protection provided for the supply circuit may still provide short-circuit protection for the branch circuit up to the point where P_2 is installed.

b) With reference to **4.4.5.2.2** and Fig. 74, the short-circuit protective device P_2 may be installed at a point on the supply side of the origin (*O*) of the branch circuit (*B*) provided that, in conformity with **4.4.5.2.2**, the maximum length between the origin of the branch circuit and the short-circuit-protective device of this branch circuit respect the specification proposed by the "triangular rule".

The maximum length of the conductor branched off at *O*, with the cross-sectional area S_2, that is protected against a short-circuit by the protective device P_1 placed at *A*, is given as length ON in the triangle BON.

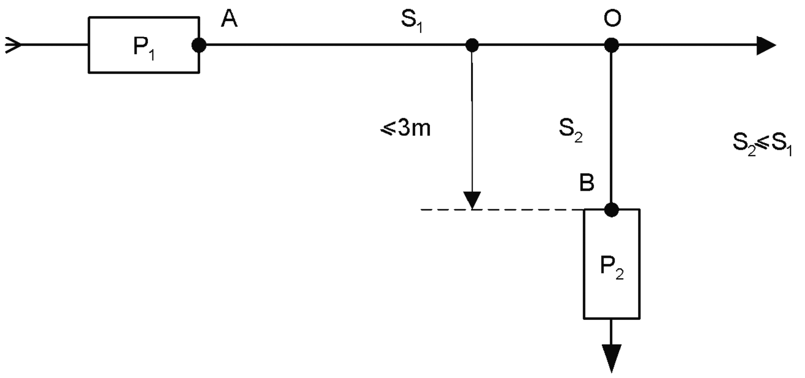
This clause may be used in the case where only protection against short-circuit is provided. Protection against overload is not considered in this example (*see* **F-3**).

These maximum lengths correspond to the minimum short-circuit capable of activating the protective device P_1. This protective device protecting branch circuit S_1 up to the length *AB* also protects the branch circuit S_2. The maximum length of branch circuit S_2 protected by P_1 depends on the location where the branch circuit S_2 is connected to S_1.

The length of branch circuit S_2 cannot exceed the value determined by the triangular diagram. In this case, the protective device P_2 may be moved along branch circuit S_2 up to the point *N*.

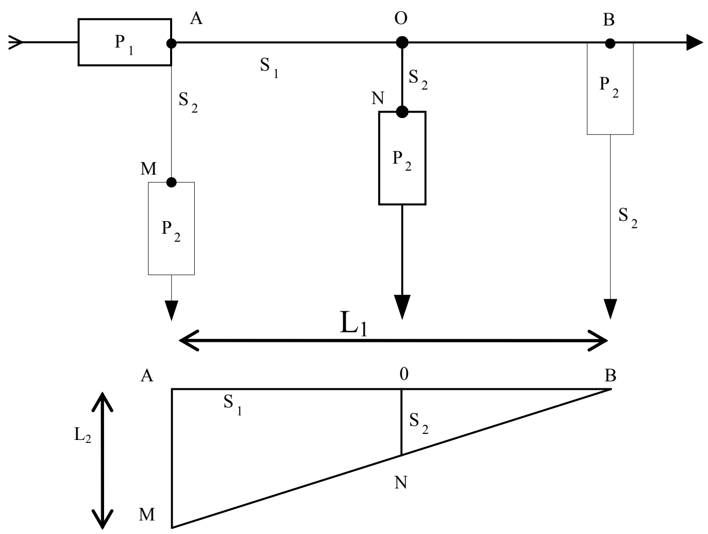
NOTES

1 This method may also be applied in the case of three successive conductor runs of different cross-sectional area.



NOTE — *S* = cross-sectional area of conductor.

FIG. 73 LIMITED CHANGE OF POSITION OF SHORT-CIRCUIT PROTECTIVE DEVICE (P_2) ON A BRANCH CIRCUIT (*see* **4.4.5.2.1**)



AB = is the maximum length L_1 of the conductor of the cross-sectional area S_1 protected against short-circuit by the protective device P_1 placed at A.

AM = is the maximum length L_2 of the conductor of the cross-sectional area S_2 protected against short-circuit by the protective device P_1placed at A.

FIG. 74 SHORT-CIRCUIT PROTECTIVE DEVICE P_2 INSTALLED AT A POINT ON THE SUPPLY SIDE OF THE ORIGIN OF A BRANCH CIRCUIT (*see* **4.4.5.2.2**)

2 If, for section S_2, the lengths of wiring differ according to the nature of insulation, the method is applicable by taking the length:

$$AB = L_2S_1/S_2$$

If, for section S_2, the lengths of wiring are the same whatever to the nature of insulation, the method is applicable by taking the length:

$$AB= L_1$$

G-3 CASE WHERE SHORT-CIRCUIT PROTECTION MAY BE OMITTED

With reference to **4.4.5.3** and Fig. 75, the short-circuit protective device may be omitted for some applications such as transformers or measuring circuits provided that, in accordance with the requirements of **4.4.5.3**, the risk of short-circuit, fire and danger to persons is reduced to a minimum.

Note that a measuring circuit employing a current transformer must not be open-circuited otherwise an overvoltage will result.

For some applications, such as a magnetic crane, short-circuit protection may be omitted (*see* **4.4.5.3**).

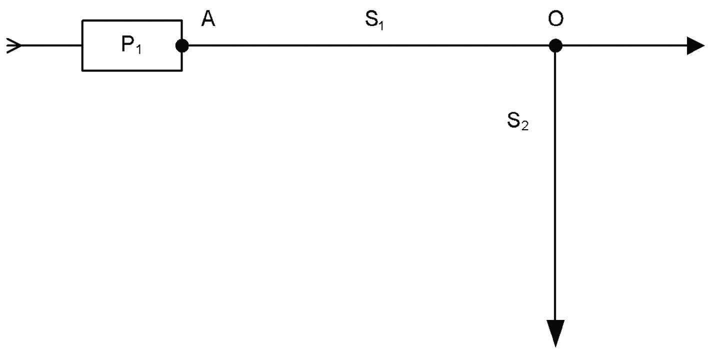


FIG. 75 SITUATION WHERE THE SHORT-CIRCUIT PROTECTIVE DEVICE MAY BE OMITTED FOR SOME APPLICATIONS (*see* **4.4.5.3**)

ANNEX H

(*Clause* 4.5)

(*Normative*)

EXPLANATORY NOTES CONCERNING 4.4.5.1 AND 4.4.5.2

H-1 GENERAL

The rules in these two clauses are intended to provide for the safety of persons and equipment in an LV system in the event of an earth-fault in the HV system.

Faults between systems at different voltages refer to those that may occur on the high-voltage side of the substation supplying a low-voltage system through a distribution system operating at a higher voltage. Such faults cause a current to flow in the earth electrode to which the exposed-conductive-parts of the substation are connected.

The magnitude of the fault-current depends on the fault-loop impedance, that is, on how the high-voltage neutral is earthed.

The fault-current flowing in the earth electrode of the exposed-conductive-parts of the substation causes a rise of the potential with respect to earth of the exposed-conductive-parts of the substation whose magnitude is governed by:

a) the fault-current magnitude, and
b) the resistance of the earth electrode of the exposed-conductive-parts of the substation.

The fault-voltage may be as high as several thousand volts and, depending on the earthing systems of the installation, may cause

a) a general rise of the potential of the exposed-conductive-parts of the low-voltage system with respect to earth, which may give rise to fault and touch-voltages;
b) a general rise of the potential of the low-voltage system with respect to earth, which may cause a breakdown in the low-voltage equipment.

It usually takes longer to clear a fault in a high-voltage system than in a low-voltage system, because the relays have time delays for discrimination against unwanted tripping on transients. The operating times of the high-voltage switchgear are also longer than for low-voltage switchgear. This means that the resulting duration of the fault-voltage and the corresponding touch-voltage on the exposed-conductive-parts of the low-voltage system may be longer than required by the LV installation rules.

There may also be a risk of breakdown in the low-voltage system of the substation or consumer's installation. The operation of protective devices under abnormal conditions of transient recovery voltages may give rise to difficulties in opening the circuit or even failure to do so.

The following fault conditions in the high-voltage system are taken into consideration:

Effectively earthed high-voltage systems

These systems include those systems where the neutral is connected to earth either directly or via a low impedance and where earth faults are cleared in a reasonably short time given by the protective equipment.

No connection of the neutral to earth in the relevant transformer substation is considered.

In general, capacitive currents are neglected.

Isolated high-voltage systems

Only single-fault conditions due to a first earth fault between a high-voltage live-part and exposed-conductive-parts of the transformer substation are taken into account. This (capacitive) current may or may not be interrupted, depending on its magnitude and the protective system.

High-voltage systems with arc-suppression coils

No arc-suppression coils in the relevant transformer substation are considered.

Where an earth fault in the high-voltage system occurs between a high-voltage conductor and the exposed-conductive-parts of the transformer substation, only small fault currents occur (residual currents mostly in the order of some tens of amperes). These currents may persist for longer times.

H-2 OVERVOLTAGES IN LV-SYSTEMS DURING A HIGH-VOLTAGE EARTH FAULT

Figure 28 has been derived from curve c2 of Fig. 20 of IS/IEC 60479-1 and was also taken as a practical proofed decision in IEC 61936-1.

When considering the values for the fault-voltage, the following should be taken into account:

a) the low risk of an earth-fault in the HV system; and
b) the fact that the touch voltage is always lower than the fault-voltage due to the main equipotential bonding required in **4.2.11.3.1.2** and the presence of additional earth electrodes at the consumer's installation or elsewhere.

Values given by ITU-T 650 V for 0.2 s and 430 V for automatic disconnection in longer than 0.2 s are slightly in excess of the values given in Fig. 28.

ANNEX J

(*Clause* 4.5)

(*Normative*)

GUIDANCE FOR OVERVOLTAGE CONTROL BY SPDs APPLIED TO OVERHEAD LINES

J-1 In the conditions of **4.5.3.3.2.1** and according to Note 1, the protective control of the overvoltage level may be obtained either by installing surge protective devices directly in the installation, or with the consent of the network operator, in the overhead lines of the supply distribution network.

As an example, the following measures may be applied:

a) in the case of overhead supply distribution networks, overvoltage protection is erected at network junction points and especially at the end of each feeder longer than 500 m. Overvoltage protective devices should be erected at every 500 m distance along the supply distribution lines. The distance between overvoltage protective devices should be less than 1 000 m;

b) if a supply distribution network is erected partly as overhead network and partly as underground network, overvoltage protection in the overhead lines should be applied in accordance with (a) at each transition point from and overhead line to an underground cable;

c) in a TN distribution network supplying electrical installations, where protection against indirect contact is provided by automatic disconnection of supply, the earthing conductors of the overvoltage protective devices connected to the line conductors are connected to the PEN conductor or to the PE conductor; and

d) in a TT distribution network supplying electrical installations, where protection against indirect contact is provided by automatic disconnection of supply, overvoltage protective devices are provided for the phase conductors and for the neutral conductor. At the place where the neutral conductor of the supply network is effectively earthed, an overvoltage protective device for the neutral conductor is not necessary.

Table 16 Different Possibilities for IT Systems (taking into account a first fault in the LV installation)

System	Exposed-Conductive-parts of LV Equipment of the Substation	Neutral Impedance, if any	Exposed-conductive parts of Equipment of the LV Installation	U_1	U_2	U_f
a	●	●	●	$U_0\sqrt{3}$	$U_0\sqrt{3}$	$R \times I_m$
b	●	●	0	$U_0\sqrt{3}$	$R \times I_m + U_0\sqrt{3}$	0[1)]
C[2)]	0	0	0	$R \times I_m + U_0\sqrt{3}$	$U_0\sqrt{3}$	0[1)]
d	0	●	●	$R \times I_m + U_0\sqrt{3}$	$U_0\sqrt{3}$	0[1)]
e[2)]	●	0	●	$R \times I_m + U_0\sqrt{3}$	$R \times I_m + U_0\sqrt{3}$	$R \times I_m$

1) In fact, U_f is equal to the product of first fault current by the resistance of the earth electrode of the exposed-conductive-parts ($R_A \times I_d$) which shall be less or equal to U_L.

Further, in systems a, b and d, the capacitive currents which flow through the first fault may increase in certain cases the value of U_f, but this is disregarded.

2) In systems c1 and e1, an impedance is installed between the neutral and earth (impedance neutral).

In systems c2 and e2, no impedance is installed between the neutral and earth (isolated neutral).

ANNEX K

(*Clause* 4.5.3.3.2.2)

(*Normative*)

DETERMINATION OF THE CONVENTIONAL LENGTH, *d*

K-1 The configuration of the low-voltage distribution line, its earthing, insulation level and the phenomena considered: (induced coupling, resistive coupling) lead to different choices for *d*. The determination proposed below represents, by convention, the worst case.

NOTE — This simplified method is based on IEC 61662.

$$d = d_1 + \frac{d_2}{K_g} + \frac{d_3}{K_t}$$

By convention *d* is limited to 1 km,

where

d_1 = the length of the low-voltage overhead supply line to the structure, limited to 1 km;

d_2 = the length of the low-voltage underground unscreened line of the structure, limited to 1 km;

d_3 = the length of the high-voltage overhead supply line of the structure, limited to 1 km;

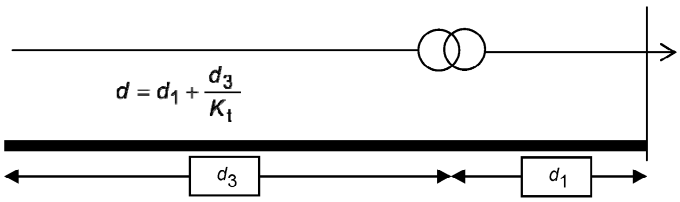
The length of a high-voltage underground supply line is neglected.

The length of a screened low-voltage underground line is neglected.

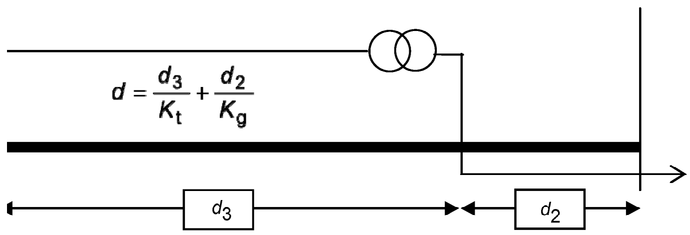
K_g = 4 is the reduction factor based on the ratio on the influence of strikes between the overhead lines and underground unscreened cables, calculated for a resistivity of soil of 250 Ωm;

K_t = 4 is the typical reduction factor for a transformer.

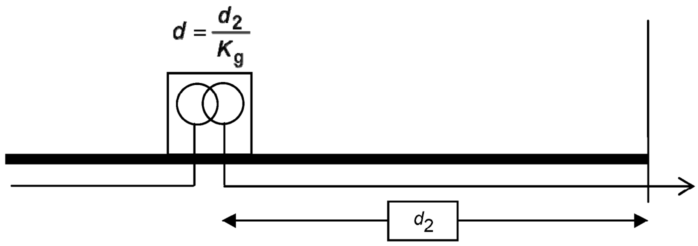
HV and LV overhead lines



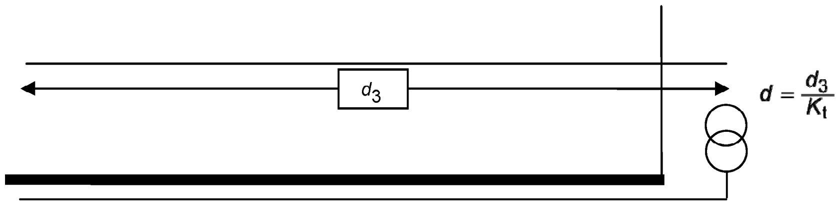
HV overhead line and buried LV lines



HV and LV buried lines



HV line overhead



NOTE — When the HV/LV transformer is inside the building, $d1 = d2 = 0$.

FIG. 76 EXAMPLES OF HOW TO APPLY d_1, d_2 AND d_3 FOR THE DETERMINATION OF d

ANNEX L

(*Clause* 5.1)

(*Normative*)

CONCISE LIST OF EXTERNAL INFLUENCES

A		*Environmental conditions*		
	AA	*Temperature (°C)*		
	AA1	–60 +5		
	AA2	–40 +5		
	AA3	–25 +5		
	AA4	–5 +40		
	AA5	+5 +40		
	AA6	+5 +60		
	AA7	–25 +55		
	AA8	–50 +40		
	AB	*Temperature and humidity*		
	AB1	–60°C +5°C	3%	100%
	AB2	–40°C +5°C	10%	100%
	AB3	–25°C +5°C	10%	100%
	AB4	–5°C +40°C	5%	95%
	AB5	+5°C +40°C	5%	85%
	AB6	+5°C +60°C	10%	100%
	AB7	–25°C +55°C10%	100%	
	AB8	–50°C +40°C15%	100%	
	AC	*Altitude (m)*		
	AC1	≤ 2 000		
	AC2	□ 2 000		
	AD	*Water*		
	AD1	Negligible		
	AD2	Drops		
	AD3	Spray		
	AD4	Splashes		
	AD5	Jets		
	AD6	Waves		
	AD7	Immersion		
	AD8	Submersion		
	AE	*Foreign bodies*		
	AE1	Negligible		
	AE2	Small		
	AE3	Very small		
	AE4	Light dust		
	AE5	Moderate dust		
	AE6	Heavy dust		
	AF	*Corrosion*		
	AF1	Negligible		
	AF2	Atmospheric		
	AF3	Intermittent		
	AF4	Continuous		
		Mechanical stress		
	AG	*Impact*		
	AG1	Low severity		
	AG2	Medium severity		
	AG3	High severity		
	AH	*Vibration*		
	AH1	Low severity		
	AH2	Medium severity		
	AH3	High severity		

AK	*Flora*
AK1	No hazard
AK2	Hazard
AL	*Fauna*
AL1	No hazard
AL2	Hazard
AM	*Electromagnetic, electrostatic, or*
	ionizing influences
	Low-frequency electromagnetic
	phenomena (conducted or
	radiated)
	Harmonics, interharmonics
	Controlled level
AM1	Normal level
AM1-1	High level
AM1-2	
AM1-3	*Signalling voltages*
	Controlled level
AM2	Normal level
AM2-1	High level
AM2-2	
AM2-3	*Voltage amplitude variations*
	Controlled level
AM3	Normal level
AM3-1	
AM3-2	*Voltage unbalance*
AM4	*Power frequency variations*
AM5	*Induced low-frequency voltages*
AM6	*Direct current in a.c. voltages*
	Radiated magnetic field
AM7	Medium level
	High level
AM8	*Electric fields*
AM8-1	Negligible level
AM8-2	Medium level
	High level
	Very high level
AM9	
AM9-1	*High frequency electromagnetic*
AM9-2	*phenomena conducted, induced or*
AM9-3	*radiated (continuous or transient)*
AM9-4	*Induced oscillatory voltages or*
	currents
AM21	

AM22	*Conducted*
	unidirectional transients
	of the nanosecond time
AM22-1	*scale*
AM22-2	Negligible level
AM22-3	Medium level
AM22-4	High level
	Very high level
AM23	*Conducted*
	unidirectional transients
	of the microsecond to
	the millisecond time
	scale
	Controlled level
	Medium level
AM23-1	High level
AM23-2	
AM23-3	*Conducted oscillatory*
	transients
	Medium level
AM24	High level
AM24-1	*Radiated high frequency*
AM24-2	*phenomena*
	Negligible level
AM25	Medium level
	High level
AM25-1	
AM25-2	*Electrostatic discharges*
AM25-3	Small level
	Medium level
AM31	High level
AM31-1	Very high level
AM31-2	
AM31-3	*Ionization*
AM31-4	
	Solar radiation
AM41	Low
	Medium
AN	High
AN1	
AN2	*Seismic effects*
AN3	Negligible
	Low severity
	Medium severity
AP	High severity
AP1	
AP2	*Lightning*
AP3	Negligible
AP4	Indirect exposure
	Direct exposure
AQ	
AQ1	*Movement of air*
AQ2	Low
AQ3	Medium
	High
AR	
AR1	*Wind*
AR2	Low
AR3	medium
	High
AS	
AS1	
AS2	
AS3	

B		*Utilization*	*BC*	*Contact of persons with earth*	*BE*	*Nature of processed or stored materials*
				None		
	BA	*Capability of persons*	BC1	Low	BE1	No significant risk
	BA1	Ordinary	BC2	Frequent	BE2	Fire risk
	BA2	Children	BC3	Continuous	BE3	Explosion risk
Utilisation	BA3	Handicapped	BC4		BE4	Contamination risk
	BA4	Instructed		*Condition of evacuation in an*		
	BA5	Skilled	*BD*	*emergency*		
				Low density/easy exit		
	BB	*Electrical resistance of the human body*	BD1	Low density/difficult exit		
			BD2	High density/easy exit		
			BD3	High density/difficult exit		
			BD4			
C		*Construction and buildings*	*CB*	*Building design*		
			CB1	Negligible risks		
	CA	*Construction materials*	CB2	Propagation of fire		
Building	CA1	Non-combustible	CB3	Movement		
	CA2	Combustible	CB4	Flexible or unstable		

ANNEX M

(*Clause* 5.1)

(*Normative*)

INTERDEPENDENCE OF AIR TEMPERATURE, RELATIVE AIR HUMIDITY AND ABSOLUTE AIR HUMIDITY

M-1 This Annex contains climatograms for each class of ambient climatic conditions, showing the interdependence of air temperature, relative air humidity and absolute air humidity by curves for constant absolute humidity and lines for temperature and relative humidity.

M-1.1 As far as air temperature is concerned, the climatogram shows the possible maximum temperature difference for any location covered by the class.

M-1.2 As far as air humidity is concerned, the climatogram comprises the complete scatter of values of relative air humidity in accordance with any air temperature occurring within the range covered by the class. The interdependence of both temperature and humidity is fixed by the values of absolute air humidity occurring within the range of the class.

M-1.3 As already stated in the notes of Table 7, the limit values of, for example, high air temperature and high relative air humidity given in the classes will normally not occur in combination. Normally higher values of air temperature will occur combined with lower values of relative air humidity.

M-1.4 Exceptions from this rule will be found for classes AB1, AB2 and AB3, where any value of relative humidity specified for the range may be combined with the highest value of air temperature. This fact should be considered in connection with the rather low value of high absolute humidity for the limit value of high air temperature in these classes.

M-1.5 To give a review of this situation, Table 17 for each class the highest value of air temperature which may occur is given together with the highest value of relative air humidity of the class. At air temperatures higher than the value given in the table the relative air humidity will be lower, that is, below the limit value of the class.

Table 17 Highest Value of Air Temperature Corresponding to Class Code

(*Clauses* 5.2.4.1 *and* M-1.5)

Class Code	Limit Value of Relative Air Humidity	Highest Value of Air Temperature to Occur with Limit Value of Relative Air Humidity
AB1	100 %	+5 °C
AB2	100 %	+5 °C
AB3	100 %	+5 °C
AB4	95 %	+31 °C
AB5	85 %	+28 °C
AB6	100 %	+33 °C
AB7	100 %	+27 °C
AB8	100 %	+33 °C

M-1.6 In practice, the climatograms may be used as follows:

> The relevant value of relative air humidity at a certain value of air temperature within the temperature range of a class may be found at the point where the curve for constant absolute air humidity cuts the straight lines for air temperature and relative air humidity respectively.

Example:

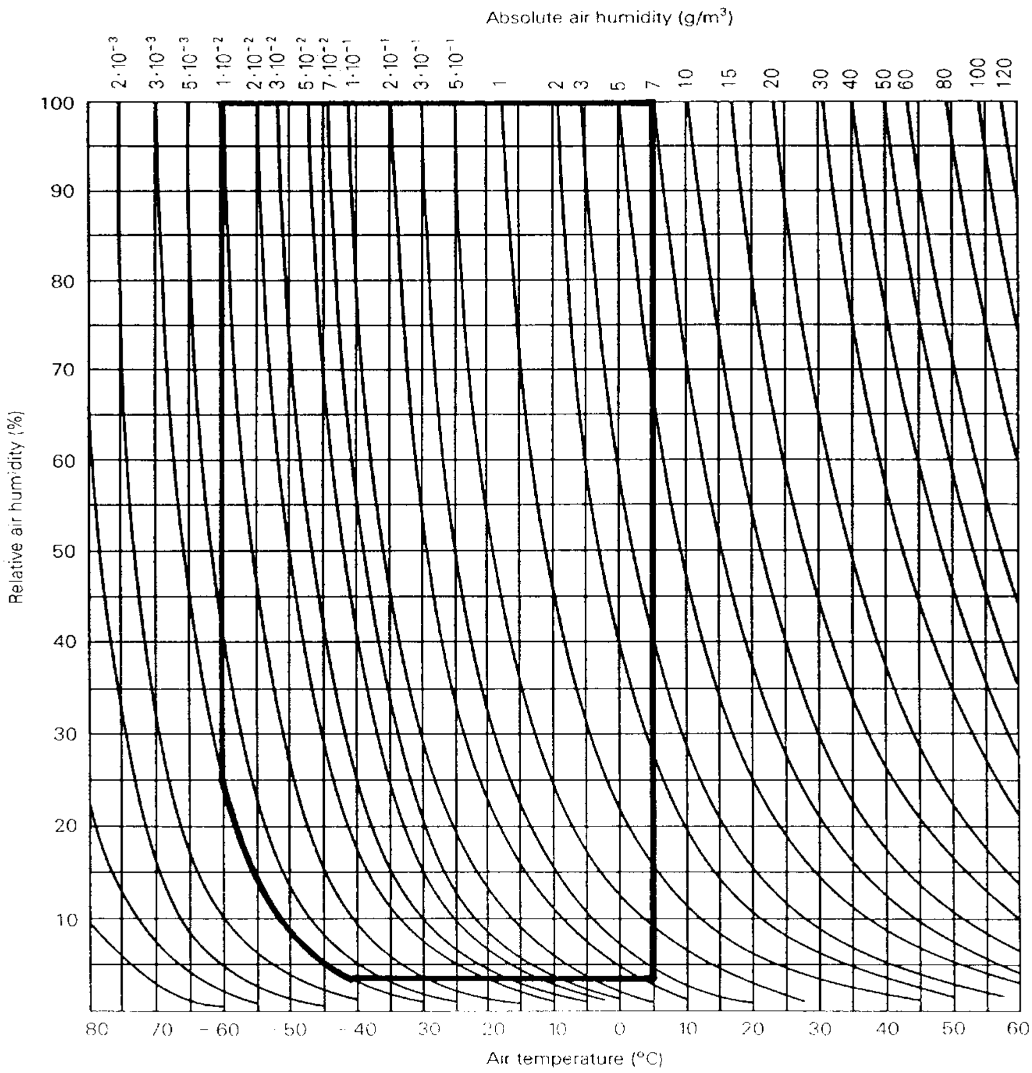
A product may be selected for installation conditions covered by class AB6. To find out which relative air humidity the product will have to withstand in the utmost at, for example, 40 °C, one follows the vertical line for air temperature 40 °C in the climatogram for class AB6 up to the point where it meets the curve for 35 g/m^3 absolute air humidity which is the limit value for high absolute air humidity for this class. From this point one draws a horizontal line to the scale of relative air humidity, and one will find a value of 67 percent relative air humidity.

Using this method, any other possible combination of air temperature and relative air humidity within the range of the class may be found, for example, in class AB6 a value of 27 percent relative air humidity will be found at the limit value of high air temperature which is 60 °C.

Climatogram

Interdependence of air temperature, relative air humidity and absolute air humidity.

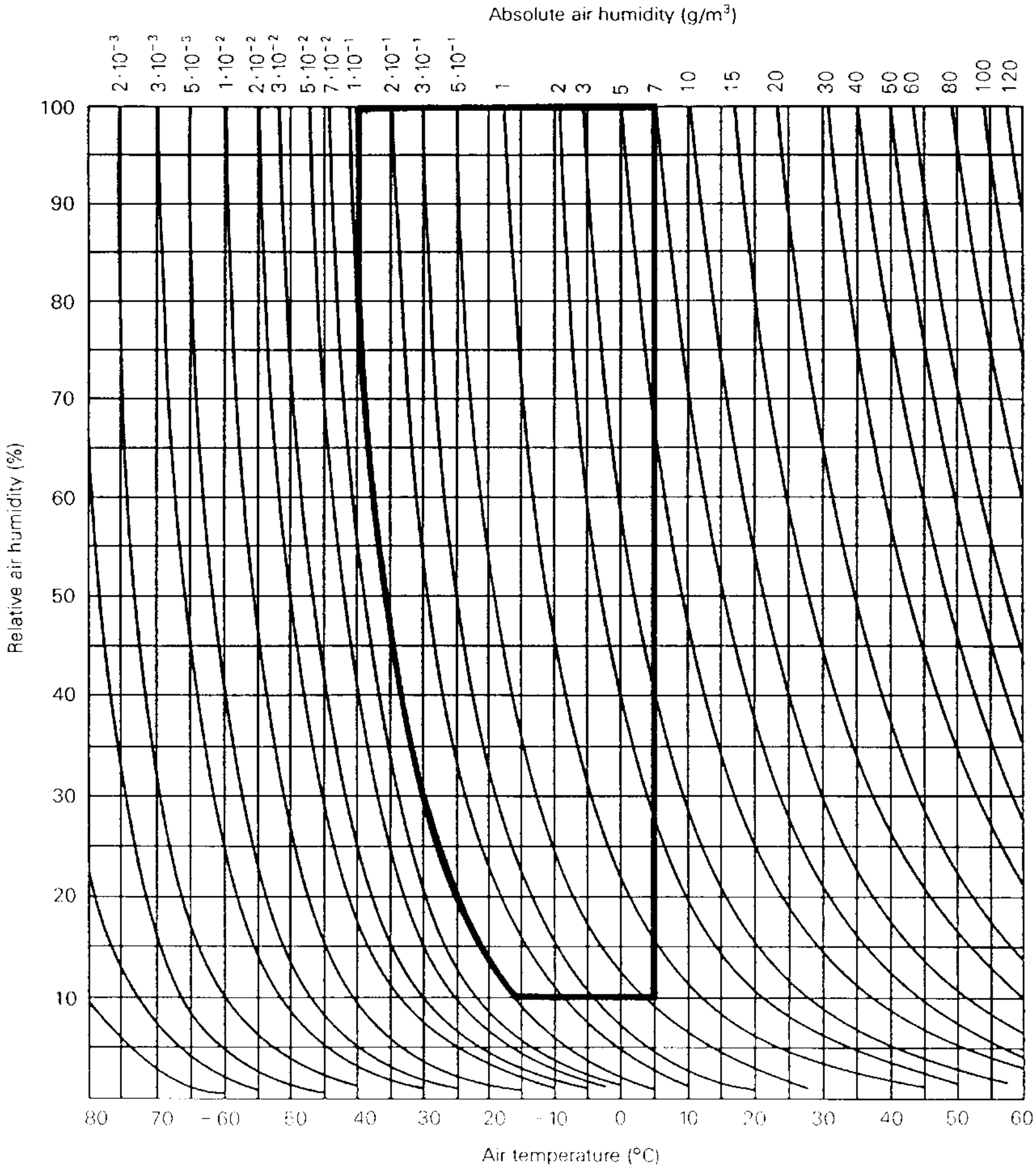
Class AB 1



Climatogram

Interdependence of air temperature, relative air humidity and absolute air humidity.

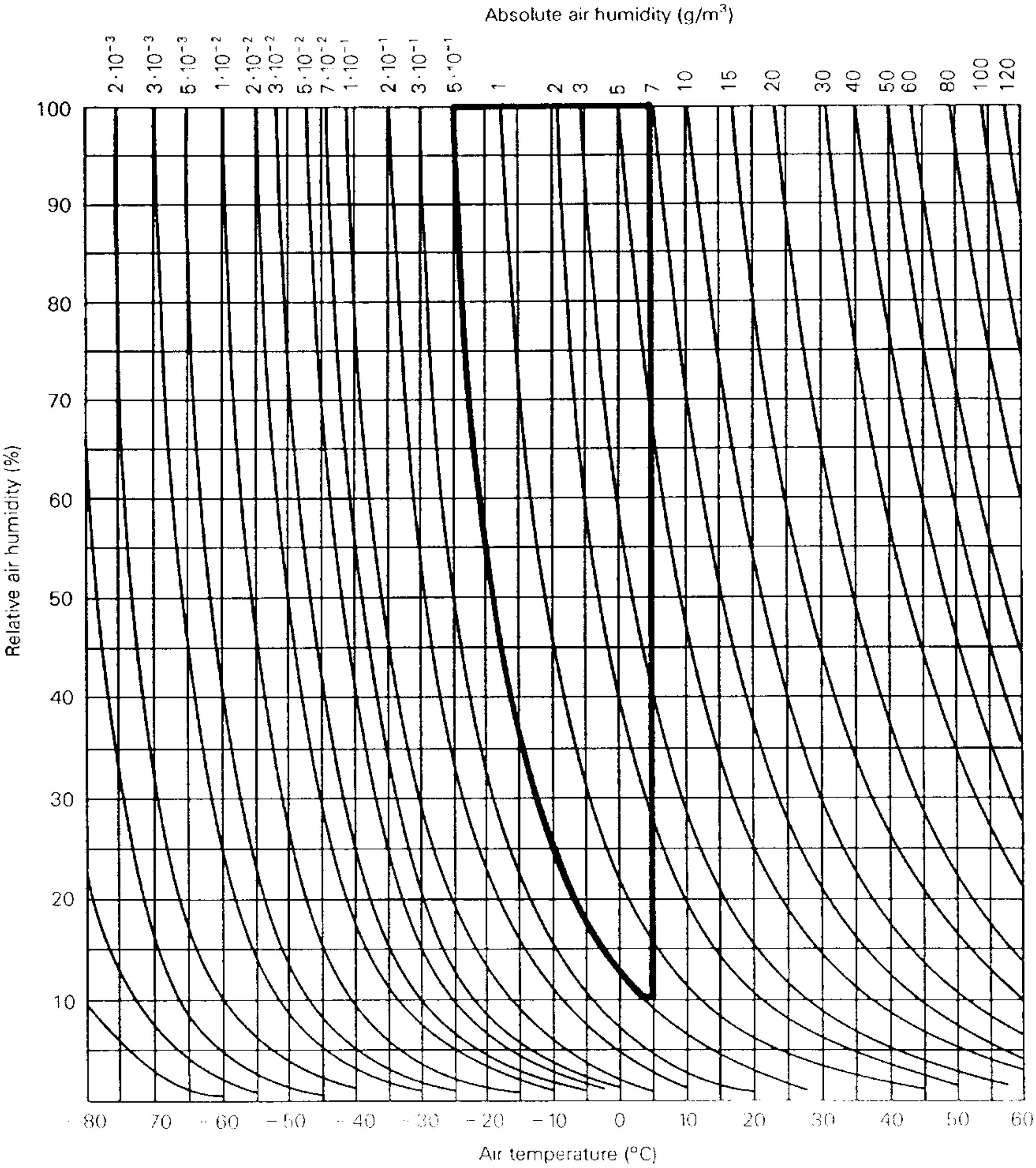
Class AB 2



Climatogram

Interdependence of air temperature, relative air humidity and absolute air humidity.

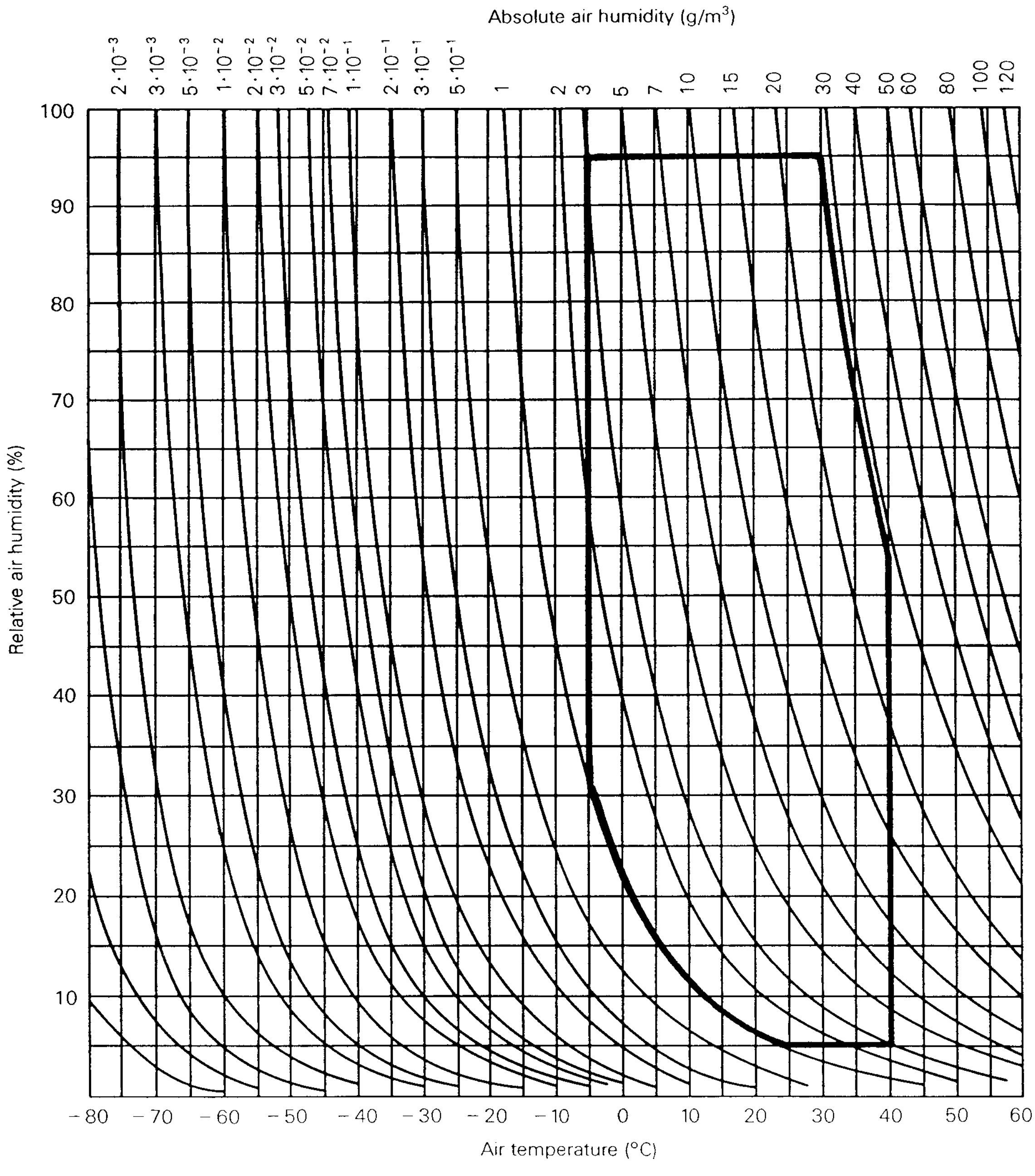
Class AB 3



Climatogram

Interdependence of air temperature, relative air humidity and absolute air humidity.

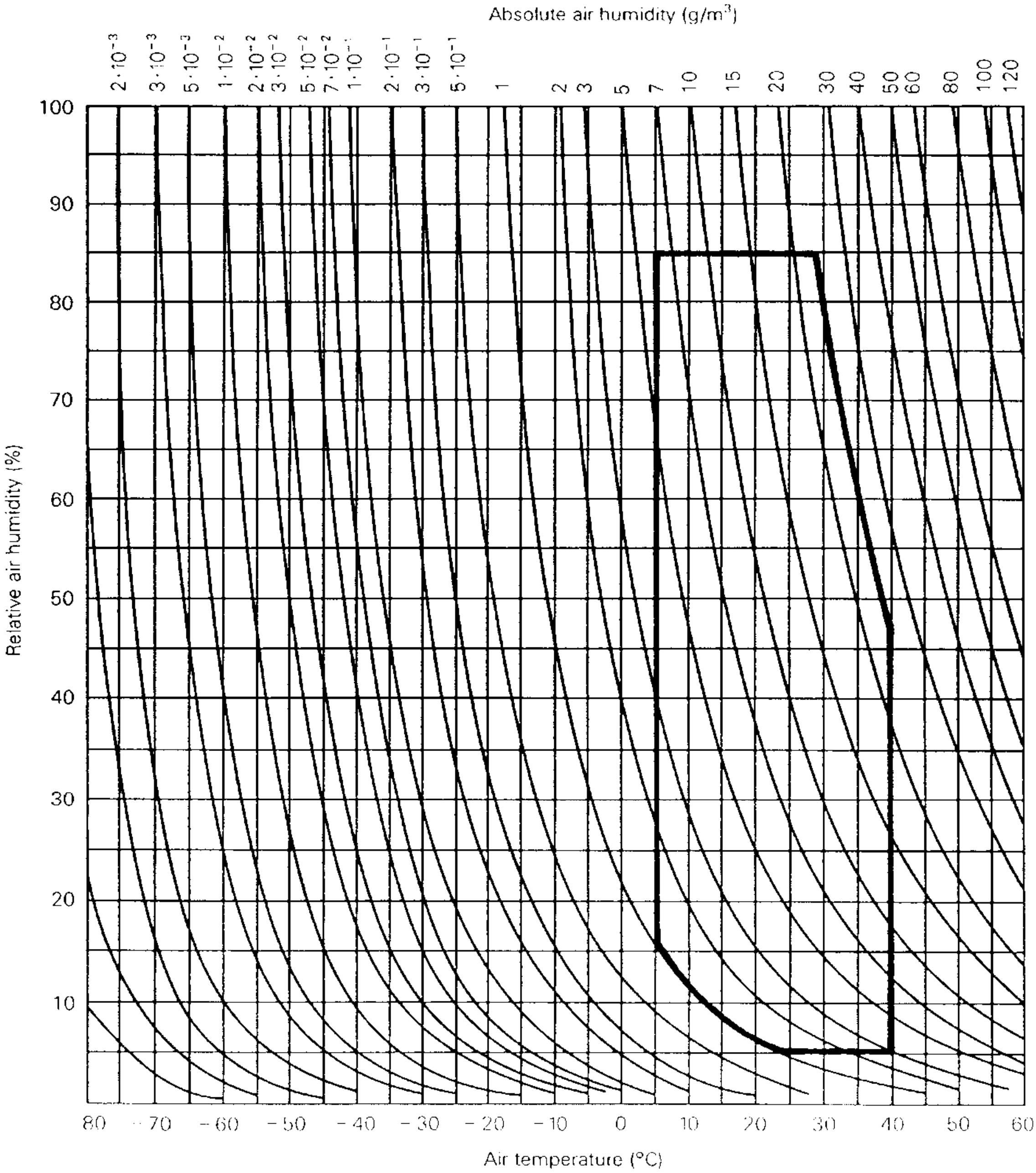
Class AB 4



Climatogram

Interdependence of air temperature, relative air humidity and absolute air humidity.

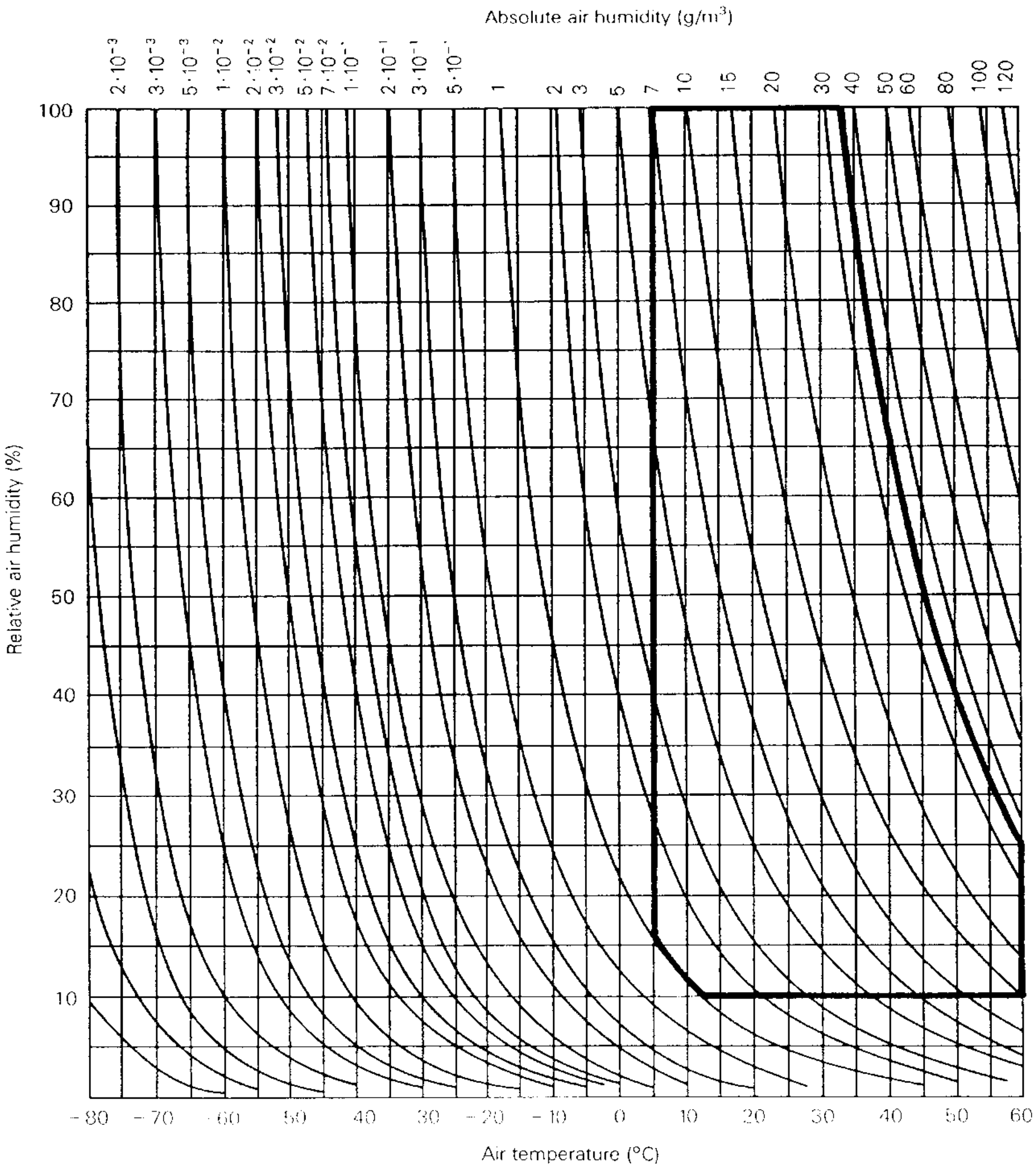
Class AB 5



Climatogram

Interdependence of air temperature, relative air humidity and absolute air humidity.

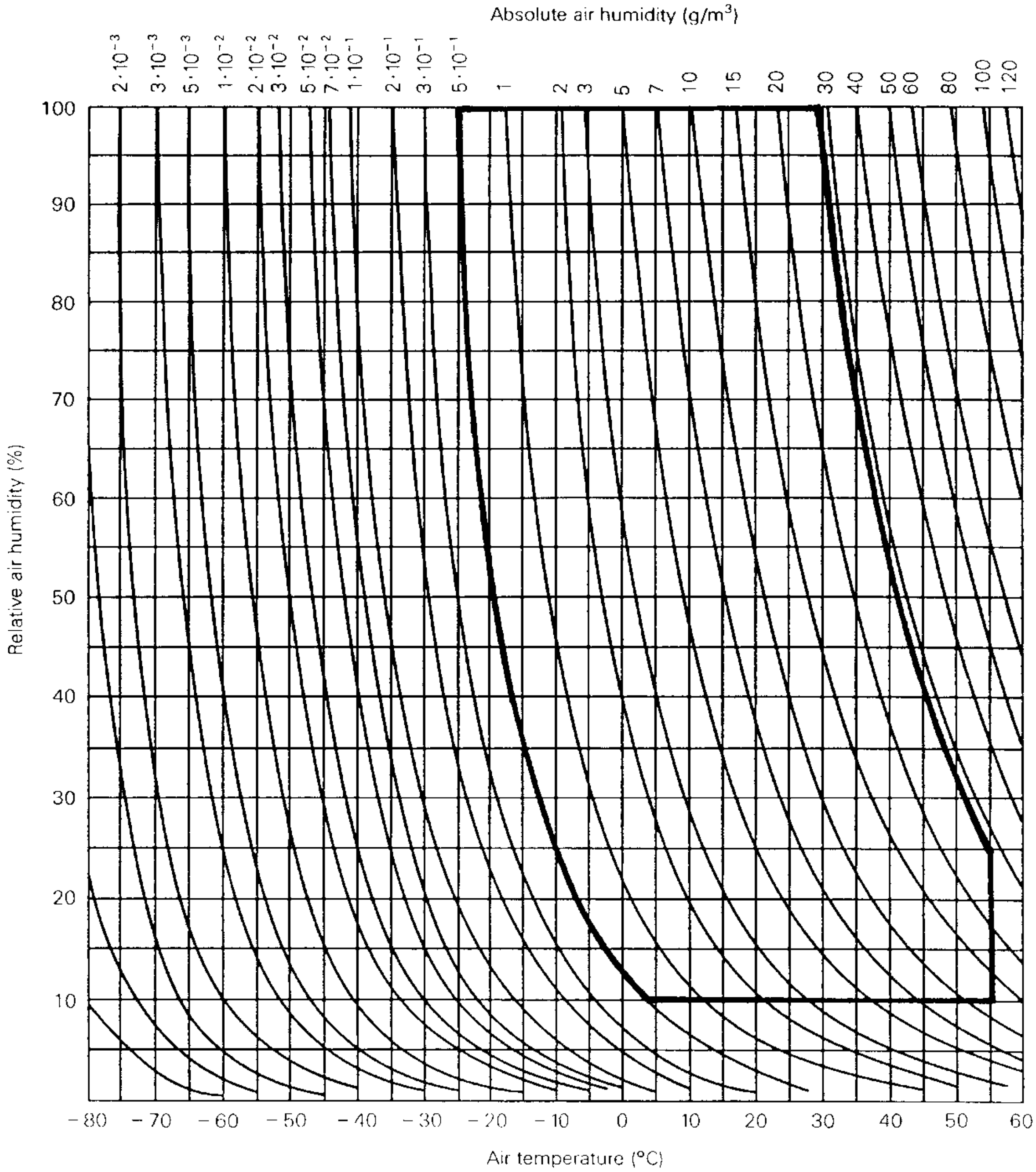
Class AB 6



Climatogram

Interdependence of air temperature, relative air humidity and absolute air humidity.

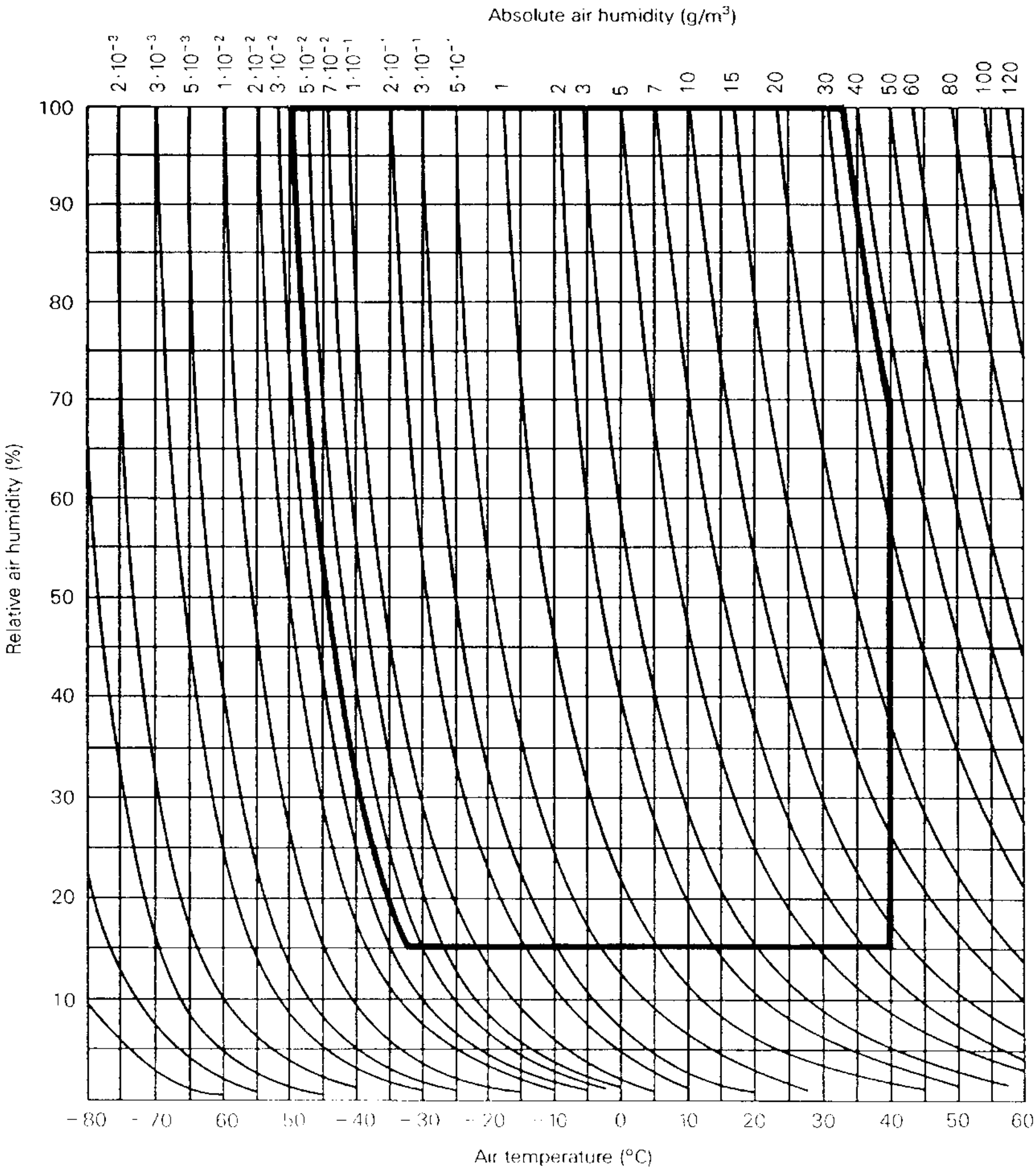
Class AB 7



Climatogram

Interdependence of air temperature, relative air humidity and absolute air humidity.

Class AB 8



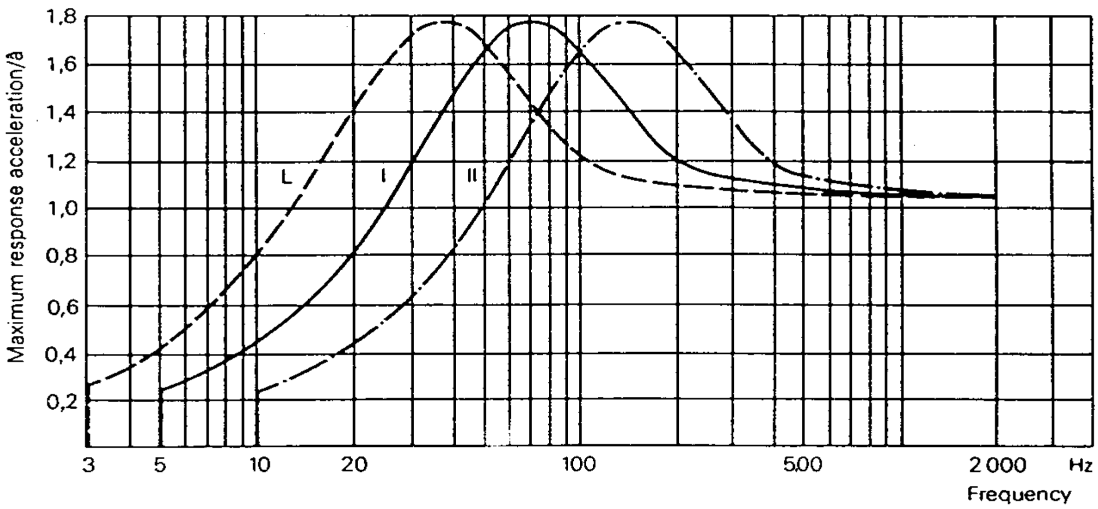
ANNEX N

(*Clause* 5.1)

(*Normative*)

CLASSIFICATION OF MECHANICAL CONDITIONS

Environmental Parameter	**Unit**	**Class**															
		AG1/AH1						AG2/AH2				AG3/AH3					
		3M1 4M1		3M2 4M2		3M3 4M3		3M4 4M4		3M5 4M5		3M6 4M6		3M7 4M7		3M8 4M8	
Stationary vibration, sinusoidal																	
Displacement amplitude	mm	0.3		1.5		1.5		3.0		3.0		7.0		10		15	
Acceleration amplitude	m/s2		1		5		5		10		10		20		30		50
Frequency range	Hz	2-9	9-200	2-9	9-200	2-9	9-200	2-9	9-200	2-9	9-200	2-9	9-200	2-9	9-200	2-9	9-200
Non-stationary vibration, including shock																	
Shock response spectrum type L (â)	m/s^2	40		40		70		–		–		–		–		–	
Shock response spectrum type I (â)	m/s^2	–		–		–		100		–		–		–		–	
Shock response spectrum type II (â)	m/s^2	–		–		–		–		250		250		250		250	
NOTE — â = maximum acceleration.																	



Spectrum type L Duration = 22 ms
Spectrum type I Duration = 11 ms
Spectrum type II Duration = 6 ms

FIG. 77 MODEL SHOCK RESPONSE SPECTRA
(FIRST ORDER "MAXIMAS" SHOCK RESPONSE SPECTRA)

ANNEX P

(Clause 5.1)
(*Normative*)

CLASSIFICATION OF MACRO-ENVIRONMENTS

Category of Environment	*Climatic Conditions*	*Chemically and Mechanically Active Substances*[1)]
I	AB 5 3K 3	AF 2/AE 1 3C 2/3S 1
II	AB 4 3K 5, but the high air temperature is restricted to +40 °C	AF 1/AE 4 3C 1/3S 2
III	AB 7 3K 6	AF 2/AE 5 3C 2/3S 3
IV	AB 8 4K 3	AF 3/AE 6 3C 3/3S 4

[1)] The first line in each box shows the class designation according to Table 7.
The second line shows the class designation according to IEC 60721-3-0.

NOTE — The macro-environment is the environment of the room or other location in which the equipment is installed or used.

ANNEX Q

(*Clause* 5.1.6)
(*Normative*)

PERMISSIBLE PROTECTIVE CONDUCTOR CURRENTS FOR EQUIPMENT

As additional information to **5.1.6**, IEC 61140 specifies protective conductor currents and their limits as follows.

NOTE — Subclauses are reproduced directly from IEC 61140.

Q-1 PROTECTIVE CONDUCTOR CURRENTS

Measures shall be taken in the installation and in equipment to prevent excessive protective conductor currents impairing safety or normal use of the electrical installation. Compatibility shall be ensured for currents of all frequencies supplied to and produced by the equipment.

Q-1.1 Requirements for the Prevention of Excessive Protective Conductor Currents of Current-using Equipment

The requirements for electrical equipment which causes, under normal operating conditions, a current to flow in its protective conductor, shall allow normal use and be compatible with protective provisions. The requirements of **7.5.2** of IEC 61140 take into account equipment intended to be supplied by plug and socket-outlet systems, or by a permanent connection, or the case of stationary equipment.

Q-1.2 Maximum a.c. Limits of Protective Conductor Currents of Current-using Equipment

NOTE — A protective conductor current measurement method, which takes into account high-frequency components weighted according to IS/ IEC 60479-2, is under consideration.

Measurements shall be carried out on equipment as delivered.

The following limits are applicable to equipment supplied at rated frequency of 50 Hz or 60 Hz.

a) Plug-in current using equipment fitted with a single or multi-phase plug and socket-outlet-system rated up to and including 32 A. Limit values are given in Annex B from IEC 61140.

b) Current-using equipment for permanent connection and current using stationary equipment, both without special measures for the protective conductor, or plug-in current using equipment fitted with a single phase or multiphase plug and socket-outlet system, rated more than 32 A. Limit values are given in Annex B from IEC 61140.
c) Current-using equipment for permanent connection intended to be connected to a reinforced protective conductor according to **7.5.2.4** of IEC 61140. Product committees should state the maximum values for the protective conductor current, which in no case shall exceed 5 percent of the rated input current per phase.

However, product committees shall consider that, for protective reasons, residual current devices may be provided in the installation, in which case, the protective conductor current shall be compatible with the protective measures provided. Alternatively a transformer with a separate winding and with at least simple separation, shall be used.

Q-1.3 d.c. Protective Conductor Current

In normal use, a.c. equipment shall not generate current with a d.c. component in the protective conductor which could affect the proper functioning of residual current devices or other equipment.

NOTE — Requirements related to fault currents with d.c. component are under consideration.

Q-1.4 Provisions in Equipment in Case of Connection to Reinforced Protective Conductor Circuits for Protective Conductor Currents exceeding 10 mA

The following shall be provided in the current-using equipment:

a) a connecting terminal designed for the connection of a protective conductor, measuring at least of 10 mm^2 Cu or 16 mm^2 Al, or
b) a second terminal designed for the connection of a protective conductor of the same cross-section as that of the normal protective conductor so as to connect a second protective conductor to the current-using equipment.

Q-1.5 Information

For equipment intended for permanent connection with reinforced protective conductor, the value of the protective conductor current shall be provided by the manufacturer in his documentation and indication shall be given in the instructions for installation, that the equipment shall be installed as described in **7.5.3** of IEC 61140.

Q-2 VALUES OF MAXIMUM ac LIMITS OF PROTECTIVE CONDUCTORS CURRENT FOR CASES Q-1.2 (A) AND Q-1.2 (B)

These values are for consideration by product committees in order to prevent excessive protective conductor currents and to provide co-ordination of electrical equipment and of protective measures within an electrical installation.

Product committees are encouraged to use the lowest practical values of protective conductor current limits.

Product committees should be aware that adoption of limits not exceeding the values below may avoid unwanted tripping of residual current devices in most cases.

*Values for **7.5.2.2(a)***

Values for plug-in current-using equipment fitted with a single phase or multiphase plug and socket-outlet system, rated up to and including 32 A:

Equipment Rated Current	*Maximum Protective Conductor Current*
≤ 4 A	2 mA
> 4 A but ≤ 10 A	0.5 mA/A
> 10 A	5 mA

*Values for **7.5.2.2(b)***

Values for current-using equipment for permanent connection and current using stationary equipment, both without special measures for the protective conductor, or plug-in current-using equipment, fitted with a single phase or multiphase plug and socket-outlet system, rated more than 32 A:

Equipment Rated Current	*Maximum Protective Conductor Current*
≤ 7 A	3.5 mA
> 7 A but ≤ 20 A	0.5 mA/A
> 20 A	10 mA

ANNEX R

(*Clause* 5.2.4.1)

(*Normative*)

METHODS OF INSTALLATIONS

Table 17 Methods of Installation in Relation to Conductors and Cables
(*Clause* 5.2.4.1)

Conductors and Cables			**Method of Installation**							
			Without Fixings	Clipped Direct	Conduit Systems	Cable Trunking Systems (Including Skirting Trunking, Flush Floor Trunking)	Cable Ducting Systems	Cable Ladder, Cable Tray, Cable Brackets	On Insulators	Support Wire
1.	Bare conductors		–	–	–	–	–	–	+	–
2.	Insulated conductors[2)]		–	–	+	+[1)]	+	–	+	–
3.	Sheathed cables (including armoured and mineral insulated)	Multi-core	+	+	+	+	+	+	0	+
		Single-core	0	+	+	+	+	+	0	+

\+ Permitted.
– Not permitted.
0 Not applicable, or not normally used in practice.

[1)] Insulated conductors are admitted if the cable trunking systems provide at least the degree of protection IP4X or IPXXD and if the cover can only be removed by means of a tool or a deliberate action.

[2)] Insulated conductors which are used as protective conductors or protective bonding conductors may use any appropriate method of installation and need not be laid in conduits, trunking or ducting systems.

Table 18 Erection of Wiring Systems
(*Clause* 5.2.4.2)

Situations		**Method of Installation**							
		Without Fixings	Clipped Direct	Conduit Systems	Cable Trunking (Including Skirting Trunking, Flush Floor Trunking)	Cable Ducting Systems	Cable Ladder, Cable Tray, Cable Brackets	On Insulators	Support Wire
Building voids	Accessible	40	33	41, 42	6, 7, 8, 9, 12	43, 44	30, 31, 32, 33, 34	–	0
	Not accessible	40	0	41,42	0	43	0	0	0
Cable channel		56	56	54, 55	0		30, 31, 32, 34	–	–
Buried in ground		72, 73	0	70, 71	–	70, 71	0	–	–
Embedded in structure		57, 58	3	1, 2, 59, 60	50, 51, 52, 53	46, 45	0	–	–
Surface mounted		–	20, 21, 22, 23, 33	4, 5	6, 7, 8, 9, 12	6, 7, 8, 9	30, 31, 32, 34	36	–
Overhead/free in air		–	33	0	10, 11	10,11	30, 31, 32,34	36	35
Window frames		16	0	16	0	0	0	-	-
Architrave		15	0	15	0	0	0	–	–
Immersed 1		+	+	+	–	+	0	–	–

– Not permitted.
0 Not applicable or not normally used in practice.
\+ Follow manufacturer's instructions.

NOTE — The number in each box, for example, 40, 46, refers to the number of the method of installation given in Table 19.

Table 19 Examples of Methods of Installation Providing Instructions for Obtaining Current-Carrying Capacity
(*Clause* 5.2.4.3)

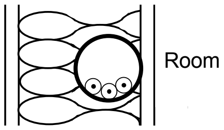
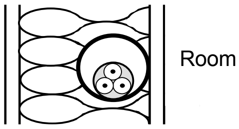
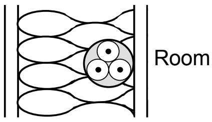
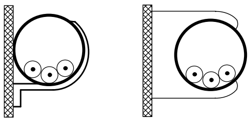
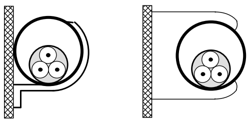
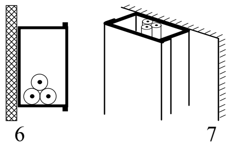
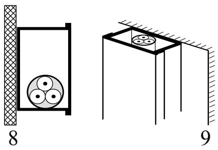
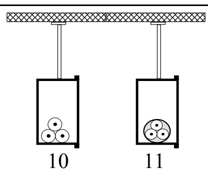
Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-Carrying Capacity (*see* Annex S)
1		Insulated conductors or single-core cables in conduit in a thermally insulated wall1[1.3)]	A1
2		Multi-core cables in conduit in a thermally insulated wall[1.3)]	A2
3		Multi-core cable direct in a thermally insulated wall[1.3)]	A1
4		Insulated conductors or single-core cables in conduit on a wooden or masonry wall or spaced less than 0.3 × conduit diameter from it[3)]	B1
5		Multi-core cable in conduit on a wooden or masonry wall or spaced less than 0.3 × conduit diameter from it[3)]	B2
6 7		Insulated conductors or single-core cables in cable trunking (includes multi-compartment trunking) on a wooden or masonry wall – run horizontally[2)] – run vertically2,3	B1
8 9		Multi-core cable in cable trunking (includes multi-compartment trunking) on a wooden or masonry wall – run horizontally[2)] – run vertically[2,3)]	Under considerationd Method B2 may be used
10		Insulated conductors or single-core cable in suspended cable trunking[2)]	B1
11		Multi-core cable in suspended cable trunking[2)]	B2

Table 19 — (*Continued*)

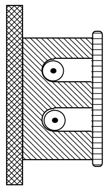
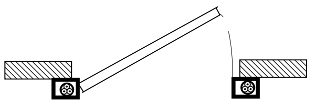
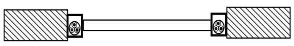
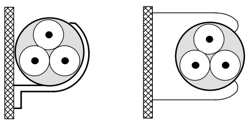
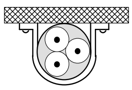
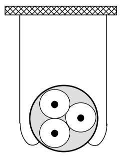
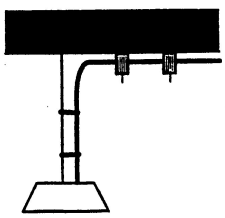
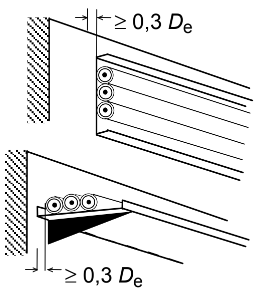
Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-Carrying Capacity (*see* Annex S)
12		Insulated conductors or single-core cable run in mouldings[3,5)]	A1
15		Insulated conductors in conduit or single-core or multi-core cable in architrave[3,6)]	A1
16		Insulated conductors in conduit or single-core or multi-core cable in window frames[3,6)]	A1
20		Single-core or multi-core cables: – fixed on, or spaced less than 0.3 × cable diameter from a wooden or masonry wall[3)]	C
21		Single-core or multi-core cables: – fixed directly under a wooden or masonry ceiling	C, with item 3 of Table 36
22		Single-core or multi-core cables: – spaced from a ceiling	Under consideration Method E may be used
23		Fixed installation of suspended current- using equipment	C, with item 3 of Table 36
30		Single-core or multi-core cables: On unperforated tray run horizontally or vertically[3,8)]	C with item 2 of Table 36

Table 19 — (*Continued*)

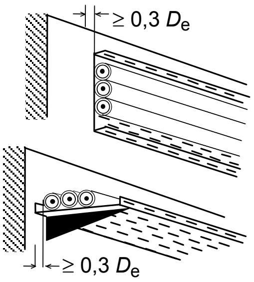
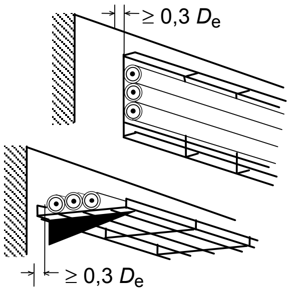
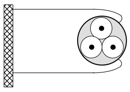
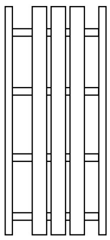
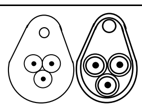
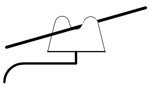
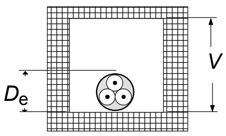
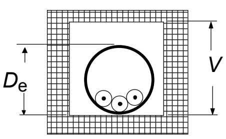
Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-Carrying Capacity (*see* Annex S)
31		Single-core or multi-core cables: On perforated tray run horizontally or vertically[3,8)] NOTE — Refer to **S-6.2** of Annex S for description	E or F
32		Single-core or multi-core cables: On brackets or on a wire mesh tray run horizontally or vertically[3,8)]	E or F
33		Single-core or multi-core cables: Spaced more than 0.3 times cable diameter from a wall	E or F or method G[7)]
34		Single-core or multi-core cables: On ladder[3)]	E or F
35		Single-core or multi-core cable suspended from or incorporating a support wire or harness	E or F
36		Bare or insulated conductors on insulators	G
40		Single-core or multi-core cable in a building void[3,8,9)]	1.5 *De* ≤ *V* < 5 *De* B2 5 *De* ≤ *V* < 20 *De* B1
41		Insulated conductor in conduit in a building void[3,9,10)]	1.5 *De* ≤ *V* < 20 *De* B2 *V*≥ 20 *De* B1

Table 19 — (*Continued*)

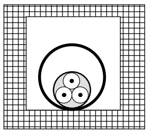
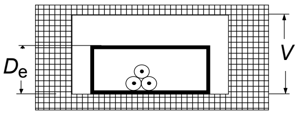
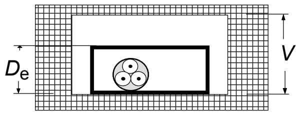
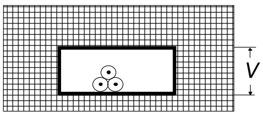
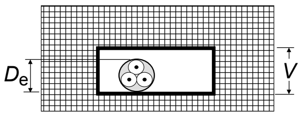
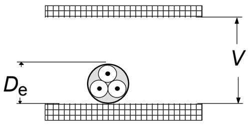
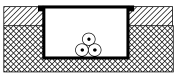
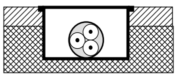
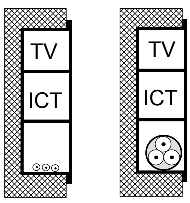
Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-Carrying Capacity (*see* Annex S)
42		Single-core or multi-core cable in conduit in a building void[3)]	Under consideration The following may be used: $1.5\,De \le V < 20\,De$ B2 $V \ge 20\,De$ B1
43		Insulated conductors in cable ducting in a building void[3,9,10)]	$1.5\,De \le V < 20\,De$ B2 $V \ge 20\,De$ B1
44		Single-core or multi-core cable in cable ducting in a building void[3)]	Under consideration The following may be used: $1.5\,De \le V < 20\,De$ B2 $V \ge 20\,De$ B1
45		Insulated conductors in cable ducting in masonry having a thermal resistivity not greater than 2 K · m/W[3,8,9)]	$1.5\,De \le V < 5\,De$ B2 $5\,De \le V < 50\,De$ B1
46		Single-core or multi-core cable in cable ducting in masonry having a thermal resistivity not greater than 2 K · m/W[3)]	Under consideration The following may be used $1.5\,De \le V < 20\,De$ B2 $V \ge 20\,De$ B1
47		Single-core or multi-core cable: – in a ceiling void – in a raised floor[8,9)]	$1.5\,De \le V < 5\,De$ B2 $5\,De \le V < 50\,De$ B1
50		Insulated conductors or single-core cable in flush cable trunking in the floor	B1
51		Multi-core cable in flush cable trunking in the floor	B2
52	52 53	Insulated conductors or single-core cables in flush cable trunking[3)]	B1
53		Multi-core cable in flush trunking[3)]	B2

Table 19 — (*Continued*)

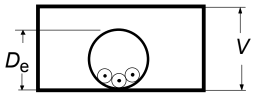
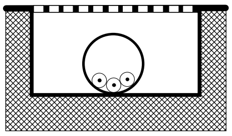
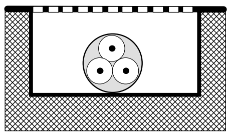
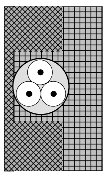
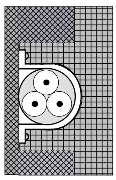
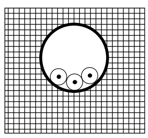
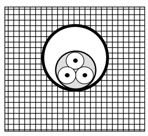
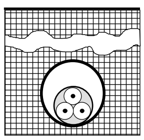
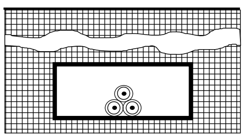
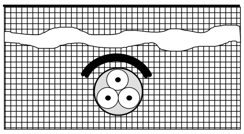
Item No.	Methods of Installation	Description	Reference Method of Installation to be Used to Obtain Current-Carrying Capacity (*see* Annex S)
54		Insulated conductors or single-core cables in conduit in an unventilated cable channel run horizontally or vertically[3,9,11,13]	$1.5\ De \leq V < 20\ De$ B2 $V \geq 20\ De$ B1
55		Insulated conductors in conduit in an open or ventilated cable channel in the floor[12,13]	B1
56		Sheathed single-core or multi-core cable in an open or ventilated cable channel run horizontally or vertically[13]	B1
57		Single-core or multi-core cable direct in masonry having a thermal resistivity not greater than 2 K · m/W Without added mechanical protection[14,15]	C
58		Single-core or multi-core cable direct in masonry having a thermal resistivity not greater than 2 K · m/W With added mechanical protection[14,15]	C
59		Insulated conductors or single-core cables in conduit in masonry[15]	B1
60		Multi-core cables in conduit in masonry[15]	B2
70		Multi-core cable in conduit or in cable ducting in the ground	D1
71		Single-core cable in conduit or in cable ducting in the ground	D1

Table 19 — (*Concluded*)

Item No.	**Methods of Installation**	**Description**	**Reference Method of Installation to be Used to Obtain Current-Carrying Capacity** (*see* Annex S)
73		Sheathed single-core or multi-core cables direct in the ground – With added mechanical protection[16)]	D2

1) The inner skin of the wall has a thermal conductance of not less than 10 $W/m^2 \cdot K$.

2) Values given for installation methods B1 and B2 in Annex S are for a single circuit. Where there is more than one circuit in the trunking the group reduction factor given in Table 36 is applicable, irrespective of the presence of an internal barrier or partition.

3) Care shall be taken where the cable runs vertically and ventilation is restricted. The ambient temperature at the top of the vertical section can be increased considerably. The matter is under consideration.

4) Values for reference method B2 may be used.

5) The thermal resistivity of the enclosure is assumed to be poor because of the material of construction and possible air spaces. Where the construction is thermally equivalent to methods of installation 6 or 7, reference method B1 may be used.

6) The thermal resistivity of the enclosure is assumed to be poor because of the material of construction and possible air spaces. Where the construction is thermally equivalent to methods of installation 6, 7, 8, or 9, reference methods B1 or B2 may be used.

7) The factors in Table 36 may also be used.

8) D_e is the external diameter of a multi-core cable:
— 2.2 × the cable diameter when three single core cables are bound in trefoil, or
—3 × the cable diameter when three single core cables are laid in flat formation.

9) V is the smaller dimension or diameter of a masonry duct or void, or the vertical depth of a rectangular duct, floor or ceiling void or channel. The depth of the channel is more important than the width.

10) D_e is the external diameter of conduit or vertical depth of cable ducting.

11) D_e is the external diameter of the conduit.

12) For multi-core cable installed in method 55, use current-carrying capacity for reference method B2.

13) It is recommended that these methods of installation are used only in areas where access is restricted to authorized persons so that the reduction in current-carrying capacity and the fire hazard due to the accumulation of debris can be prevented.

14) For cables having conductors not greater than 16 mm^2, the current-carrying capacity may be higher.

15) Thermal resistivity of masonry is not greater than 2 $K \cdot m/W$, the term “masonry” is taken to include brickwork, concrete, plaster and the like (other than thermally insulating materials).

16) The inclusion of directly buried cables in this item is satisfactory when the soil thermal resistivity is of the order of 2.5 $K \cdot m/W$. For lower soil resistivity, the current-carrying capacity for directly buried cables is appreciably higher than for cables in ducts.

ANNEX S

(*Clause* 5.2.6.2)
(*Normative*)

CURRENT-CARRYING CAPACITIES

S-1 INTRODUCTION

The recommendations of this Annex are intended to provide for a satisfactory life of conductor and insulation subjected to the thermal effects of carrying current for prolonged periods of time in normal service. Other considerations affect the choice of the cross-sectional area of conductors, such as the requirements for protection against electric shock (*see* **4.2**), protection against thermal effects (*see* **4.3**), overcurrent protection (*see* **4.4**), voltage drop (*see* **5.2.8**), and limiting temperatures for terminals of equipment to which the conductors are connected (*see* **5.2.9**).

For the time being, this Annex relates to non-armoured cables and insulated conductors having a nominal voltage not exceeding 1 kV a.c. or 1.5 kV d.c. This Annex may be applied for armoured multi-core cables but does not apply to armoured single-core cables.

NOTES

1 If armoured single-core cables are used, an appreciable reduction of the current-carrying capacities given in the annex may be required. The cable supplier should be consulted. This is also applicable to non-armoured single-core cables in single way metallic ducts (*see* **5.2.4.5**).

2 If armoured multi-core cables are used, the values given in this Annex will be on the safe side.

3 Current-carrying capacities of insulated conductors are the same as for single core cables.

The values given in Table 21 to Table 32 apply to cables without armour and have been derived in accordance with the methods given in IEC 60287 series using such dimensions as specified in IEC 60502 and conductor resistances given in IS 8130. Known practical variations in cable construction (for example, form of conductor) and manufacturing tolerances result in a spread of possible dimensions and hence current-carrying capacities for each conductor size. Tabulated current-carrying capacities have been selected so as to take account of this spread of values with safety and to lie on a smooth curve when plotted against conductor cross-sectional area.

For multi-core cables having conductors with a cross-sectional area of 25 mm^2 or larger, either circular or shaped conductors are permissible. Tabulated values have been derived from dimensions appropriate to shaped conductors.

S-2 AMBIENT TEMPERATURE

S-2.1 The current-carrying capacities tabulated in this Annex assume the following reference ambient temperatures:

a) for insulated conductors and cables in air, irrespective of the method of installation: 30 °C; and
b) for buried cables, either directly in the soil or in ducts in the ground: 20 °C.

S-2.2 Where the ambient temperature in the intended location of the insulated conductors or cables differs from the reference ambient temperature, the appropriate correction factor given in Tables 33 and 34 shall be applied to the values of current-carrying capacity set out in Tables 21 to 32. For buried cables, further correction is not needed if the soil temperature exceeds the chosen ambient temperature by an amount up to 5 K for only a few weeks a year.

NOTE — For cables and insulated conductors in air, where the ambient temperature occasionally exceeds the reference ambient temperature, the possible use of the tabulated current-carrying capacities without correction is under consideration.

S-2.3 The correction factors in Tables 33 and 34 do not take account of the increase, if any, due to solar or other infra-red radiation. Where the cables or insulated conductors are subject to such radiation, the current-carrying capacity may be derived by the methods specified in IEC 60287 series.

S-3 SOIL THERMAL RESISTIVITY

The current-carrying capacities tabulated in this Annex for cables in the ground relate to a soil thermal resistivity of 2.5 K·m/W. This value is considered necessary as a precaution for worldwide use when the soil type and geographical location are not specified (*see* IEC 60287-3-1).

In locations where the effective soil thermal resistivity is higher than 2.5 K·m/W, an appropriate reduction in current-carrying capacity should be made or the soil immediately around the cables shall be replaced by a more suitable material. Such cases can usually be recognized by very dry ground conditions. Correction factors for soil thermal resistivities other than 2.5 K·m/W are given in Table 35.

NOTE — The current-carrying capacities tabulated in this Annex for cables in the ground are intended to relate only to runs in and around buildings. For other installations, where investigations establish more accurate values of soil thermal

resistivity appropriate for the load to be carried, the values of current-carrying capacity may be derived by the methods of calculation given in IEC 60287 series or obtained from the cable manufacturer.

S-4 GROUPS CONTAINING MORE THAN ONE CIRCUIT

S-4.1 Installation Types A to D in Table 20

The current-carrying capacities given in Tables 21 to Table 26 relate to single circuits consisting of the following numbers of conductors:

a) two insulated conductors or two single-core cables, or one twin-core cable; and
b) three insulated conductors or three single-core cables, or one three-core cable.

Where more insulated conductors or cables, other than bare mineral insulated cables not exposed to touch, are installed in the same group, the group reduction factors specified in Tables 36 to Table 38 shall be applied.

NOTE — The group reduction factors have been calculated on the basis of prolonged steady-state operation at a 100 percent load factor for all live conductors. Where the loading is less than 100 percent as a result of the conditions of operation of the installation, the group reduction factors may be higher.

S-4.2 Installation Types E and F in Table 20

The current-carrying capacities of Tables 27 to Table 32 relate to the reference methods of installation.

For installations on perforated cable trays, cleats and the like, current-carrying capacities for both single circuits and groups are obtained by multiplying the capacities given for the relevant arrangements of insulated conductors or cables in free air, as indicated in Tables 27 to Table 32, by the installation and group reduction factors given in Tables 39 and 40. No group reduction factors are required for bare mineral insulated cables not exposed to touch (*see* Tables 26 and 28).

The following notes concern **S-4.1** and **S-4.2**:

NOTES

1 Group reduction factors have been calculated as averages for the range of conductor sizes, cable types and installation conditions considered. Attention is drawn to the notes under each table. In some instances, a more precise calculation may be desirable.

2 Group reduction factors have been calculated on the basis that the group consists of similar equally loaded insulated conductors or cables. When a group contains various sizes of cable or insulated conductor, caution should be exercised over the current loading of the smaller ones (*see* **S-5**).

S-5 GROUPS CONTAINING DIFFERENT SIZES

Tabulated group reduction factors are applicable to groups consisting of similar equally loaded cables. The calculation of reduction factors for groups containing different sizes of equally loaded insulated conductors or cables is dependent on the total number in the group and the mix of sizes. Such factors cannot be tabulated but shall be calculated for each group. The method of calculation of such factors is outside the scope of this standard. Some specific examples of where such calculations may be advisable are given below.

NOTE — A group containing sizes of conductor spanning a range of more than three adjacent standard sizes may be considered as a group containing different sizes. A group of similar cables is taken to be a group where the current-carrying capacity of all the cables is based on the same maximum permissible conductor temperature and where the range of conductor sizes in the group spans not more than three adjacent standard sizes.

S-5.1 Groups in Conduit Systems, Cable Trunking Systems or Cable Ducting Systems

The group reduction factor which is on the safe side, for a group containing different sizes of insulated conductors or cables in conduit systems, cable trunking systems or cable ducting systems is:

$$F = \frac{1}{\sqrt{n}}$$

where

F = the group reduction factor; and

n = the number of multi-core cables or the number of circuits in the group.

The group reduction factor obtained by this equation will reduce the danger of overloading the smaller sizes but may lead to under-utilization of the larger sizes. Such under-utilization can be avoided if large and small sizes of cable or insulated conductor are not mixed in the same group.

The use of a method of calculation specifically intended for groups containing different sizes of insulated conductors or cables in conduit will produce a more precise group reduction factor. This subject is under consideration.

S-5.2 Groups on Trays

When a group contains different sizes of cable, caution shall be exercised over the current loading of smaller sizes. It is preferable to use a method of calculation specifically intended for groups containing different sizes of cables.

The group reduction factor obtained in accordance with **S-5.1** will provide a value which is on the safe side. This subject is under consideration.

S-6 METHODS OF INSTALLATION

S-6.1 Reference Methods

The reference methods are those methods of

installation for which the current-carrying capacity has been determined by test or calculation.

a) **Reference methods A1**, item 1 of Table 19 (insulated conductors in conduit in a thermally insulated wall) and **A2**, item 2 of Table 19 (multi-core cable in conduit in a thermally insulated wall):

The wall consists of an outer weatherproof skin, thermal insulation and an inner skin of wood or wood-like material having a thermal conductance of at least 10 $W/m^2 \cdot K$. The conduit is fixed so as to be close to, but not necessarily touching the inner skin. Heat from the cables is assumed to escape through the inner skin only. The conduit can be metal or plastic.

b) **Reference methods B1**, item 4 of Table 19 (insulated conductors in conduit on a wooden wall) and **B2,** item 5 of Table 19, (multi-core cable in conduit on a wooden wall):

Conduit mounted on a wooden wall so that the gap between the conduit and the surface is less than 0.3 times the conduit diameter. The conduit can be metal or plastic. Where the conduit is fixed to a masonry wall the current-carrying capacity of the cable or insulated conductors may be higher. This subject is under consideration.

c) **Reference method C**, item 20 of Table 19 (single-core or multi-core cable on a wooden wall):

Cable mounted on a wooden wall so that the gap between the cable and the surface is less than 0.3 times the cable diameter. Where the cable is fixed to or embedded in a masonry wall the current-carrying capacity may be higher. This subject is under consideration.

NOTE — The term "masonry" is taken to include brickwork, concrete, plaster and the like (other than thermally insulating materials).

d) **Reference method D1**, item 70 of Table 19 (multi-core cable in ducts in the ground) and **D2** (multi-core cables designed to be buried directly in the ground – refer to manufacturer's instructions):

Cables drawn into 100 mm diameter plastic, earthenware or metallic ducts laid in direct contact with soil having a thermal resistivity of 2.5 K·m/W and a depth of 0.7 m (*see also* **S-3**).

Cables laid in direct contact with soil having thermal resistivity of 2.5 K·m/W and a depth of 0.7 m (*see* also **S-3**).

NOTE — With cables laid in the ground it is important to limit the temperature of the sheath. If the heat of the sheath dries out the soil, thermal resistivity may increase and the cable becomes overloaded. One way of avoiding this heating is to use the tables for 70 °C conductor temperature even for cables designed for 90 °C.

e) **Reference methods E, F and G**, items 32 and 33 of Table 19 (single-core or multi-core cable in free air):

A cable so supported that the total heat dissipation is not impeded. Heating due to solar radiation and other sources shall be taken into account. Care shall be taken that natural air convection is not impeded. In practice, a clearance between a cable and any adjacent surface of at least 0.3 times the cable external diameter for multi-core cables or 1 time the cable diameter for single-core cables is sufficient to permit the use of current-carrying capacities appropriate to free air conditions.

S-6.2 Other Methods

a) **Cable on a floor or under a ceiling**: this is similar to reference method C except that the current-carrying capacity for a cable on a ceiling is slightly reduced (*see* Table 36) from the value for a wall or a floor because of the reduction in natural convection.

b) **Cable tray system**: a perforated cable tray has a regular pattern of holes so as to facilitate the use of cable fixings. The current-carrying capacity for cables on perforated cable trays have been derived from test work utilizing trays where the holes occupied 30 percent of the area of the base. If the holes occupy less than 30 percent of the area of the base, the cable tray is regarded as unperforated. This is similar to reference method C.

c) **Cable ladder system**: this construction offers a minimum of impedance to the air flow around the cables, that is, supporting metal work under the cables occupies less than 10 percent of the plan area.

d) **Cable cleats, cable ties:** devices for fixing cables to cable tray or bundling cables together.

e) **Cable hangers:** cable supports which hold the cable at intervals along its length and permit substantially complete free air flow around the cable.

General notes to Table 20 to Table 40.

NOTES

1 Current-carrying capacities are tabulated for those types of insulated conductor and cable and methods of

installation which are commonly used for fixed electrical installations. The tabulated capacities relate to continuous steady-state operation (100 % load factor) for d.c. or a.c. of nominal frequency 50 Hz or 60 Hz.

2 Table 20 itemizes the reference methods of installation to which the tabulated current-carrying capacities refer. It is not implied that all these items are necessarily recognized in national rules of all countries.

3 For convenience where computer-aided installation design methods are employed, the current-carrying capacities in Tables 21 to Table 32 can be related to conductor size by simple formulae. These formulae with appropriate coefficients are given in Annex U.

f) **Cables in a ceiling:** this is similar to reference method A. It may be necessary to apply the correction factors due to higher ambient temperatures that may arise in the junction boxes and similar mounted in the ceiling.

NOTE — Where a junction box in the ceiling is used for supply to a luminaire, the heat dissipation from the luminaire may provide higher ambient temperatures than prescribed in Tables 21 to Table 24 (*see also* **5.2.5.1**). The temperature may be between 40 °C and 50 °C, and a correction factor according to "Table 33" has to be applied.

Table 20 Installation Reference Methods Forming Basis of Tabulated Current-Carrying Capacities
(*Clauses* S-1, S-2.2 *and* S-4.1)

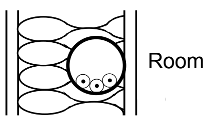
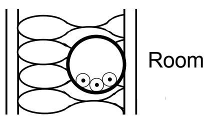
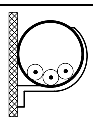
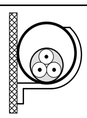
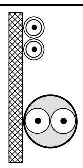
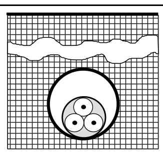
Reference Method of Installation			**Table and Column**						
			Current-Carrying for Single Circuits					Ambient Temperature Factor	Group Reduction Factor
			Thermoplastic Insulated		Thermosetting Insulated		Mineral Insulated		
			Number of Cores						
			2	3	2	3	2 and 3		
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Insulated conductors (single- core cables) in conduit in a thermally insulated wall	A1	21 col 2	23 col 2	22 col 2	24 col 2	–	33	36
	Multi-core cable in conduit in a thermally insulated wall	A2	21 col 3	23 col 3	22 col 3	24 col 3	–	33	36 except D (Table 38 applies)
	Insulated conductors (single- core cables) in conduit on a wooden wall	B1	21 col 4	23 col 4	22 col 4	24 col 4	–	33	36
	Multi-core cable in conduit on a wooden wall	B2	21 col 5	23 col 5	22 col 5	24 col 5	–	33	36
	Single-core or multi-core cable on a wooden wall	C	21 col 6	23 col 6	22 col 6	24 col 6	70 °C Sheath 25 105 °C Sheath 26	33	36
	Multi-core cable in ducts in the ground	D1	21 col 7	23 col 7	22 col 7	24 col 7	–	34	38

Table 20 — (*Concluded*)

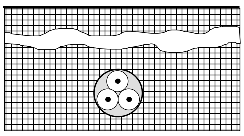
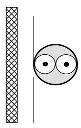
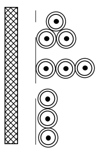
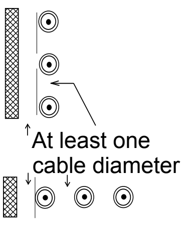
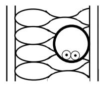
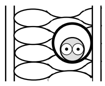
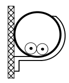
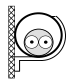
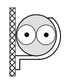
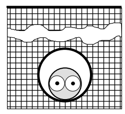
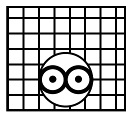
Reference Method of Installation		**Table and Column**						
		Current-Carrying Capacities for Single Circuits					Ambient Temperature Factor	Group Reduction Factor
		Thermoplastic Insulated		Thermosetting Insulated		Mineral Insulated		
		Number of cores						
		2	3	2	3	2 and 3		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
 Sheathed single-core or multi-core cables direct in the ground.	D2	col 8		col 8		col 8	col 8	col 8
 Clearance to wall not less than 0,3 times cable diameter Multi-core cable in free air	E	Copper 29 Aluminium 30		Copper 31 Aluminium 32		70 °C Sheath 27 105 °C Sheath 28	33	39
 Clearance to wall not less than one cable diameter Single-core cables, touching in free air	F	Copper 29 Aluminium 30		Copper 31 Aluminium 32		70 °C Sheath 27 105 °C Sheath 28	33	40
 Single-core cables, spaced in free air	G	Copper 29 Aluminium 30		Copper 31 Aluminium 32		70 °C Sheath 27 105 °C Sheath 28	33	—

Table 21 Current-Carrying Capacities in Amperes for Methods of Installation in Table 20
PVC Insulation/Two Loaded Conductors, Copper or Aluminium—Conductor Temperature: 70 °C, Ambient Temperature: 30 °C in Air, 20 °C in Ground

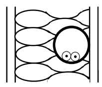
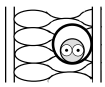
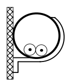
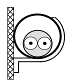
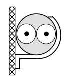
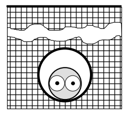
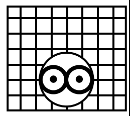
(*Clauses* S-1, S-2.2 *and* S-4.1)

Nominal Cross-sectional Area of Conductor Mm^2	Installation Methods of Table 20						
	A1	A2	B1	B2	C	D1	D2
							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copper							
1.5	14.5	14	17.5	16.5	19,5	22	22
2.5	19.5	18.5	24	23	27	29	28
4	26	25	32	30	36	37	38
6	34	32	41	38	46	46	48
10	46	43	57	52	63	60	64
16	61	57	76	69	85	78	83
25	80	75	101	90	112	99	110
35	99	92	125	111	138	119	132
50	119	110	151	133	168	140	156
70	151	139	192	168	213	173	192
95	182	167	232	201	258	204	230
120	210	192	269	232	299	231	261
150	240	219	300	258	344	261	293
185	273	248	341	294	392	292	331
240	321	291	400	344	461	336	382
300	367	334	458	394	530	379	427
Aluminium							
2.5	15	14.5	18.5	17.5	21	22	
4	20	19,5	25	24	28	29	
6	26	25	32	30	36	36	
10	36	33	44	41	49	47	
16	48	44	60	54	66	61	63
25	63	58	79	71	83	77	82
35	77	71	97	86	103	93	98
50	93	86	118	104	125	109	117
70	118	108	150	131	160	135	145
95	142	130	181	157	195	159	173
120	164	150	210	181	226	180	200
150	189	172	234	201	261	204	224
185	215	195	266	230	298	228	255
240	252	229	312	269	352	262	298
300	289	263	358	308	406	296	336

NOTE — In columns 3, 5, 6, 7 and 8, circular conductors are assumed for sizes up to and including 16 mm2. Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

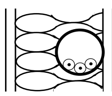
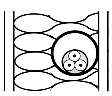
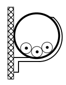
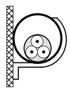
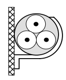
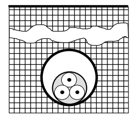
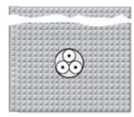
Table 22 Current-carrying Capacities in Amperes for Methods of Installation in Table 20 XLPE or EPR Insulation, Two Loaded Conductors/Copper or Aluminium – Conductor Temperature: 90 °C, Ambient Temperature: 30 °C in Air, 20 °C in Ground

(*Clauses* S-1, S-2.2 *and* S-4.1)

Nominal Cross-Sectional Area of Conductor mm^2	Installation Methods of Table 20						
	A1	A2	B1	B2	C	D1	D2
							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copper							
1.5	19	18.5	23	22	24	25	27
2.5	26	25	31	30	33	33	35
4	35	33	42	40	45	43	46
6	45	42	54	51	58	53	58
10	61	57	75	69	80	71	77
16	81	76	100	91	107	91	100
25	106	99	133	119	138	116	129
35	131	121	164	146	171	139	155
50	158	145	198	175	209	164	183
70	200	183	253	221	269	203	225
95	241	220	306	265	328	239	270
120	278	253	354	305	382	271	306
150	318	290	393	334	441	306	343
185	362	329	449	384	506	343	387
240	424	386	528	459	599	395	448
300	486	442	603	532	693	446	502
Aluminium							
2.5	20	19.5	25	23	26	26	
4	27	26	33	31	35	33	
6	35	33	43	40	45	42	
10	48	45	59	54	62	55	
16	64	60	79	72	84	71	76
25	84	78	105	94	101	90	98
35	103	96	130	115	126	108	117
50	125	115	157	138	154	128	139
70	158	145	200	175	198	158	170
95	191	175	242	210	241	186	204
120	220	201	281	242	280	211	233
150	253	230	307	261	324	238	261
185	288	262	351	300	371	267	296
240	338	307	412	358	439	307	343
300	387	352	471	415	508	346	386

NOTE — In columns 3, 5, 6, 7 and 8, circular conductors are assumed for sizes up to and including 16 mm2. Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

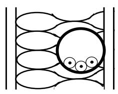
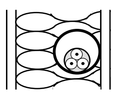
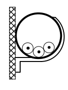
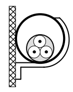
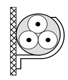
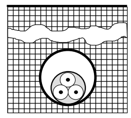
Table 23 Current-carrying Capacities in Amperes for Methods of Installation in Table 20
PVC Insulation, Three Loaded Conductors/Copper or Aluminium—Conductor Temperature: 70 °C, Ambient Temperature: 30 °C in Air, 20 °C in Ground
(*Clauses* S-1, S-2.2 *and* S-4.1)

Nominal Cross-sectional Area of Conductor mm^2	Installation Methods of Table 20						
	A1	A2	B1	B2	C	D1	D2
							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copper							
1.5	13.5	13	15.5	15	17.5	18	19
2.5	18	17.5	21	20	24	24	24
4	24	23	28	27	32	30	33
6	31	29	36	34	41	38	41
10	42	39	50	46	57	50	54
16	56	52	68	62	76	64	70
25	73	68	89	80	96	82	92
35	89	83	110	99	119	98	110
50	108	99	134	118	144	116	130
70	136	125	171	149	184	143	162
95	164	150	207	179	223	169	193
120	188	172	239	206	259	192	220
150	216	196	262	225	299	217	246
185	245	223	296	255	341	243	278
240	286	261	346	297	403	280	320
300	328	298	394	339	464	316	359
Aluminium							
2.5	14	13.5	16,5	15.5	18.5	18.5	
4	18.5	17.5	22	21	25	24	
6	24	23	28	27	32	30	
10	32	31	39	36	44	39	
16	43	41	53	48	59	50	53
25	57	53	70	62	73	64	69
35	70	65	86	77	90	77	83
50	84	78	104	92	110	91	99
70	107	98	133	116	140	112	122
95	129	118	161	139	170	132	148
120	149	135	186	160	197	150	169
150	170	155	204	176	227	169	189
185	194	176	230	199	259	190	214
240	227	207	269	232	305	218	250
300	261	237	306	265	351	247	282

NOTE — In columns 3, 5, 6, 7 and 8, circular conductors are assumed for sizes up to and including 16 mm2. Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

Table 24 Current-Carrying Capacities in Amperes for Methods of Installation in Table 20 XLPE or EPR Insulation, Three Loaded Conductors/Copper or Aluminium — Conductor Temperature: 90 °C, Ambient Temperature: 30 °C in Air, 20 °C in Ground

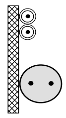
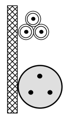
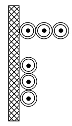
(*Clauses* S-1, S-2.2 *and* S-4.1)

Nominal Cross-sectional Area of Conductor mm^2	Installation Methods of Table 20						
	A1	A2	B1	B2	C	D1	D2
							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copper							
1.5	17	16.5	20	19.5	22	21	23
2.5	23	22	28	26	30	28	30
4	31	30	37	35	40	36	39
6	40	38	48	44	52	44	49
10	54	51	66	60	71	58	65
16	73	68	88	80	96	75	84
25	95	89	117	105	119	96	107
35	117	109	144	128	147	115	129
50	141	130	175	154	179	135	153
70	179	164	222	194	229	167	188
95	216	197	269	233	278	197	226
120	249	227	312	268	322	223	257
150	285	259	342	300	371	251	287
185	324	295	384	340	424	281	324
240	380	346	450	398	500	324	375
300	435	396	514	455	576	365	419
Aluminium							
2.5	19	18	22	21	24	22	
4	25	24	29	28	32	28	
6	32	31	38	35	41	35	
10	44	41	52	48	57	46	
16	58	55	71	64	76	59	64
25	76	71	93	84	90	75	82
35	94	87	116	103	112	90	98
50	113	104	140	124	136	106	117
70	142	131	179	156	174	130	144
95	171	157	217	188	211	154	172
120	197	180	251	216	245	174	197
150	226	206	267	240	283	197	220
185	256	233	300	272	323	220	250
240	300	273	351	318	382	253	290
300	344	313	402	364	440	286	326

NOTE— In columns 3, 5, 6, 7 and 8, circular conductors are assumed for sizes up to and including 16 mm2. Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

Table 25 Current-Carrying Capacities in Amperes for Installation Method C of Table 20 Mineral Insulation, Copper Conductors and Sheath — PVC Covered or Bare Exposed to Touch (*see* Note 2) — Metallic Sheath Temperature: 70 °C, Reference Ambient Temperature: 30 °C

(*Clauses* S-1, S-2.2 *and* S-4.1)

Nominal Cross-Sectional Area of Conductor mm^2	Number and Arrangement of Conductors for Method C of Table 20		
	Two Loaded Conductors Twin or Single-Core	Three Loaded Conductors	
		Multi-Core or Single-Core in Trefoil Formation	Single-Core in Flat Formation
			
(1)	(2)	(3)	(4)
500 V			
1.5	23	19	21
2.5	31	26	29
4	40	35	38
750V			
1.5	25	21	23
2.5	34	28	31
4	45	37	41
6	57	48	52
10	77	65	70
16	102	86	92
25	133	112	120
35	163	137	147
50	202	169	181
70	247	207	221
95	296	249	264
120	340	286	303
150	388	327	346
185	440	371	392
240	514	434	457

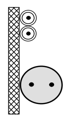
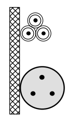
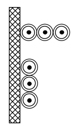
NOTES

1 For single-core cables the sheaths of the cables of the circuit are connected together at both ends.

2 For bare cables exposed to touch, values should be multiplied by 0.9.

3 The values of 500 V and 750 V are the rated voltage of the cable.

Table 26 Current-Carrying Capacities in Amperes for Installation Method C of Table 20
Mineral Insulation, Copper Conductors and Sheath —
Bare Cable not Exposed to Touch and not in Contact with Combustible Material
Metallic Sheath Temperature: 105 °C, Reference Ambient Temperature: 30 °C
(*Clauses* S-1, S-2.2 *and* S-4.1)

Nominal Cross-Sectional Area of Conductor mm^2	**Number and Arrangement of Conductors for Method C of Table 20**		
	Two Loaded Conductors Twin or Single-Core	Three Loaded Conductors	
		Multi-Core or Single-Core in Trefoil Formation	Single-Core in Flat Formation
			
(1)	(2)	(3)	(4)
500 V			
1.5	28	24	27
2.5	38	33	36
4	51	44	47
750 V			
1.5	31	26	30
2.5	42	35	41
4	55	47	53
6	70	59	67
10	96	81	91
16	127	107	119
25	166	140	154
35	203	171	187
50	251	212	230
70	307	260	280
95	369	312	334
120	424	359	383
150	485	410	435
185	550	465	492
240	643	544	572

NOTES

1 For single-core cables, the sheaths of the cables of the circuit are connected together at both ends.

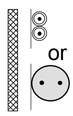
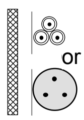
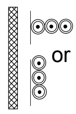
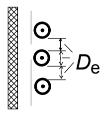
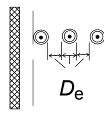
2 No correction for grouping need be applied.

3 For this table reference method C refers to a masonry wall because the high sheath temperature is not normally acceptable for a wooden wall.

4 The values of 500 V and 750 V are the rated voltage of the cable.

Table 27 Current-Carrying Capacities in Amperes for Installation Methods E, F and G of Table 20 Mineral Insulation, Copper Conductors and Sheath/PVC Covered or Bare Exposed to Touch (*see* Note 2) – Metallic Sheath Temperature: 70 °C, Reference Ambient Temperature: 30 °C

(*Clauses* S-1, S-2.2 *and* S-4.2)

Nominal Cross-Sectional Area of Conductor mm^2	Number and Arrangement of Cables for Methods E, F and G of Table 20				
	Two Loaded Conductors Twin Or Single-Core	Three loaded conductors			
	Method E or F	Multi-Core or Single-Core in Trefoil Formation Method E or F	Single-Core Touching Method F	Single-Core Flat Vertical Spaced Method G	Single-Core Horizontal Spaced Method G
					
(1)	(2)	(3)	(4)	(5)	(6)
500 V					
1.5	25	21	23	26	29
2.5	33	28	31	34	39
4	44	37	41	45	51
750 V					
1.5	26	22	26	28	32
2.5	36	30	34	37	43
4	47	40	45	49	56
6	60	51	57	62	71
10	82	69	77	84	95
16	109	92	102	110	125
25	142	120	132	142	162
35	174	147	161	173	197
50	215	182	198	213	242
70	264	223	241	259	294
95	317	267	289	309	351
120	364	308	331	353	402
150	416	352	377	400	454
185	472	399	426	446	507
240	552	466	496	497	565

NOTES

1 For single-core cables the sheaths of the cables of the circuit are connected together at both ends.

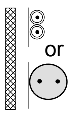
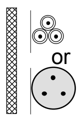
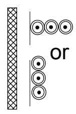
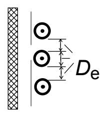
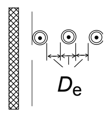
2 For bare cables exposed to touch, values should be multiplied by 0,9.

3 *De* is the external diameter of the cable.

4 The values of 500 V and 750 V are the rated voltage of the cable.

Table 28 Current-Carrying capacities in Amperes for Installation Methods E, F and G of Table 20 Mineral Insulation, Copper Conductors and Sheath — Bare Cable not Exposed to Touch (*see* Note 2) — Metallic Sheath Temperature: 105 °C, Reference Ambient Temperature: 30 °C

(*Clauses* S-1, S-2.2 *and* S-4.2)

Nominal Cross-Sectional Area of Conductor mm^2	Number and Arrangement of Cables for Methods E, F and G of Table 20				
	Two Loaded Conductors, Twin or Single-Core	Three loaded conductors			
		Multi-Core or Single-Core in Trefoil Formation	Single-Core Touching	Single-Core Flat Vertical Spaced	Single-Core Horizontal Spaced
	Method E or F	Method E or F	Method F	Method G	Method G
					
(1)	(2)	(3)	(4)	(5)	(6)
500 V					
1.5	31	26	29	33	37
2.5	41	35	39	43	49
4	54	46	51	56	64
750 V					
1.5	33	28	32	35	40
2.5	45	38	43	47	54
4	60	50	56	61	70
6	76	64	71	78	89
10	104	87	96	105	120
16	137	115	127	137	157
25	179	150	164	178	204
35	220	184	200	216	248
50	272	228	247	266	304
70	333	279	300	323	370
95	400	335	359	385	441
120	460	385	411	441	505
150	526	441	469	498	565
185	596	500	530	557	629
240	697	584	617	624	704

NOTES

1 For single-core cables the sheaths of the cables of the circuit are connected together at both ends.

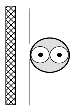
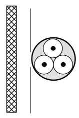
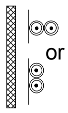
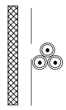
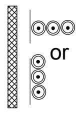
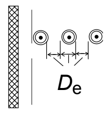
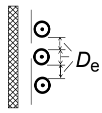
2 No correction for grouping need be applied.

3 D_e is the external diameter of the cable.

4 The values of 500 V and 750 V are the rated voltage of the cable.

Table 29 Current-Carrying Capacities in Amperes for Installation Methods E, F and G of Table 20 PVC Insulation, Copper Conductors – Conductor Temperature: 70 °C, Reference Ambient Temperature: 30 °C

(*Clauses* S-1, S-2.2 *and* S-4.2)

Nominal Cross-Sectional Area of Conductor mm^2	Installation Methods of Table 20						
	Multi-core Cables		Single-core Cables				
	Two Loaded Conductors	Three Loaded Conductors	Two Loaded Conductors Touching	Three Loaded Conductors Trefoil	Three Loaded Conductors, Flat		
					Touching	Spaced	
						Horizontal	Vertical
	 Method E	 Method E	 Method F	 Method F	 Method F	 Method G	 Method G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7)
1.5	22	18.5	–	–	–	–	–
2.5	30	25	–	–	–	–	–
4	40	34	–	–	–	–	–
6	51	43	–	–	–	–	–
10	70	60	–	–	–	–	–
16	94	80	–	–	–	–	–
25	119	101	131	110	114	146	130
35	148	126	162	137	143	181	162
50	180	153	196	167	174	219	197
70	232	196	251	216	225	281	254
95	282	238	304	264	275	341	311
120	328	276	352	308	321	396	362
150	379	319	406	356	372	456	419
185	434	364	463	409	427	521	480
240	514	430	546	485	507	615	569
300	593	497	629	561	587	709	659
400	–	–	754	656	689	852	795
500	–	–	868	749	789	982	920
630	–	–	1 005	855	905	1 138	1 070

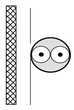
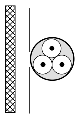
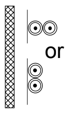
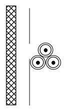
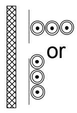
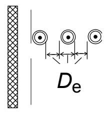
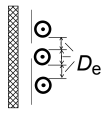
NOTES

1 Circular conductors are assumed for sizes up to and including 16 mm^2. Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

2 D_e is the external diameter of the cable.

Table 30 Current-Carrying Capacities in Amperes for Installation Methods E, F and G of Table 20 PVC Insulation, Aluminium Conductors – Conductor Temperature: 70 °C, Reference Ambient Temperature: 30 °C

(*Clauses* S-1, S-2.2 *and* S-4.2)

Nominal Cross-Sectional Area of Conductor mm2	Installation Methods of Table 20						
	Multi-core Cables		Single-core Cables				
	Two Loaded Conductors	Three Loaded Conductors	Two Loaded Conductors Touching	Three Loaded Conductors Trefoil	Three Loaded Conductors, Flat		
					Touching	Spaced	
						Horizontal	Vertical
	 Method E	 Method E	 Method F	 Method F	 Method F	 Method G	 Method G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2.5	23	19.5	–	–	–	–	–
4	31	26	–	–	–	–	–
6	39	33	–	–	–	–	–
10	54	46	–	–	–	–	–
16	73	61	–	–	–	–	–
25	89	78	98	84	87	112	99
35	111	96	122	105	109	139	124
50	135	117	149	128	133	169	152
70	173	150	192	166	173	217	196
95	210	183	235	203	212	265	241
120	244	212	273	237	247	308	282
150	282	245	316	274	287	356	327
185	322	280	363	315	330	407	376
240	380	330	430	375	392	482	447
300	439	381	497	434	455	557	519
400	–	–	600	526	552	671	629
500	–	–	694	610	640	775	730
630	–	–	808	711	746	900	852

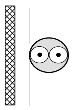
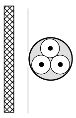
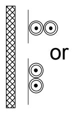
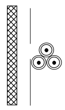
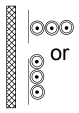
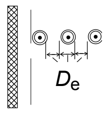
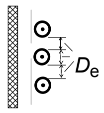
NOTES

1 Circular conductors are assumed for sizes up to and including 16 mm2. Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

2 D_e is the external diameter of the cable.

Table 31 Current-Carrying Capacities in Amperes for Installation Methods E, F and G of Table 20 XLPE or EPR Insulation, Copper Conductors — Conductor Temperature: 90 °C, Reference Ambient Temperature: 30 °C

(*Clauses* S-1, S-2.2 *and* S-4.2)

Nominal Cross-Sectional Area of Conductor mm^2	**Installation Methods of Table 20**						
	Multi-core Cables		Single-core cables				
	Two Loaded Conductors	Three Loaded Conductors	Two Loaded Conductors Touching	Three Loaded Conductors Trefoil	Three Loaded Conductors, Flat		
					Touching	Spaced	
						Horizontal	Vertical
	 Method E	 Method E	 Method F	 Method F	 Method F	 Method G	 Method G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.5	26	23	–	–	–	–	–
2.5	36	32	–	–	–	–	–
4	49	42	–	–	–	–	–
6	63	54	–	–	–	–	–
10	86	75	–	–	–	–	–
16	115	100	–	–	–	–	–
25	149	127	161	135	141	182	161
35	185	158	200	169	176	226	201
50	225	192	242	207	216	275	246
70	289	246	310	268	279	353	318
95	352	298	377	328	342	430	389
120	410	346	437	383	400	500	454
150	473	399	504	444	464	577	527
185	542	456	575	510	533	661	605
240	641	538	679	607	634	781	719
300	741	621	783	703	736	902	833
400	–	–	940	823	868	1085	1008
500	–	–	1083	946	998	1253	1169
630	–	–	1 254	1 088	1 151	1 454	1 362

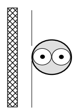
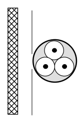
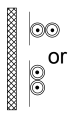
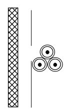
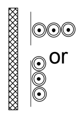
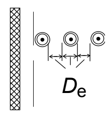
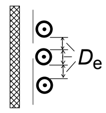
NOTES

1 Circular conductors are assumed for sizes up to and including 16 mm^2. Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

2 D_e is the external diameter of the cable.

Table 32 Current-Carrying Capacities in Amperes for Installation Methods E, F and G of Table 20 XLPE or EPR insulation. Aluminium Conductors — Conductor Temperature: 90 °C, Reference Ambient Temperature: 30 °C

(*Clauses* S-1, S-2.2 *and* S-4.2)

Nominal Cross-Sectional Area of Conductor mm^2	**Installation Methods of Table 20**						
	Multi-core Cables		Single-core Cables				
	Two Loaded Conductors	Three Loaded Conductors	Two Loaded Conductors Touching	Three Loaded Conductors Trefoil	Three Loaded Conductors, Flat		
					Touching	Spaced	
						Horizontal	Vertical
	 Method E	 Method E	 Method F	 Method F	 Method F	 Method G	 Method G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2.5	28	24	–	–	–	–	–
4	38	32	–	–	–	–	–
6	49	42	–	–	–	–	–
10	67	58	–	–	–	–	–
16	91	77	–	–	–	–	–
25	108	97	121	103	107	138	122
35	135	120	150	129	135	172	153
50	164	146	184	159	165	210	188
70	211	187	237	206	215	271	244
95	257	227	289	253	264	332	300
120	300	263	337	296	308	387	351
150	346	304	389	343	358	448	408
185	397	347	447	395	413	515	470
240	470	409	530	471	492	611	561
300	543	471	613	547	571	708	652
400	–	–	740	663	694	856	792
500	–	–	856	770	806	991	921
630	–	–	996	899	942	1 154	1 077

NOTES

1 Circular conductors are assumed for sizes up to and including 16 mm^2. Values for larger sizes relate to shaped conductors and may safely be applied to circular conductors.

2 D_e is the external diameter of the cable.

Table 33 Correction Factor for Ambient Air Temperatures Other Than 30 °C to be Applied to the Current-Carrying Capacities for Cables in the Air
(*Clause* S-2.3)

Ambient Temperature °C	Insulation			
	PVC	XLPE and EPR	Mineral[1)]	
			PVC Covered or Bare and Exposed to Touch 70 °C	Bare not Exposed to Touch 105 °C
(1)	(2)	(3)	(4)	(5)
10	1.22	1.15	1.26	1.14
15	1.17	1.12	1.20	1.11
20	1.12	1.08	1.14	1.07
25	1.06	1.04	1.07	1.04
30	1.00	1.00	1.00	1.00
35	0.94	0.96	0.93	0.96
40	0.87	0.91	0.85	0.92
45	0.79	0.87	0.78	0.88
50	0.71	0.82	0.67	0.84
55	0.61	0.76	0.57	0.80
60	0.50	0.71	0.45	0.75
65	–	0.65	–	0.70
70	–	0.58	–	0.65
75	–	0.50	–	0.60
80	–	0.41	–	0.54
85	–	–	–	0.47
90	–	–	–	0.40
95	–	–	–	0.32

1) For higher ambient temperatures, consult the manufacturer.

Table 34 Correction Factors for Ambient Ground Temperatures Other Than 20 °C to be Applied to the Current-Carrying Capacities for Cables in Ducts in the Ground
(*Clauses* S-2.2 *and* S-3)

Ground Temperature °C	**Insulation**	
	PVC	XLPE and EPR
(1)	(2)	(3)
10	1.10	1.07
15	1.05	1.04
20	1.00	1.00
25	0.95	0.96
30	0.89	0.93
35	0.84	0.89
40	0.77	0.85
45	0.71	0.80
50	0.63	0.76
55	0.55	0.71
60	0.45	0.65
65	–	0.60
70	–	0.53
75	–	0.46
80	–	0.38

Table 35 Correction Factors for Cables Buried Direct in the Ground or in Buried Ducts for Soil Thermal Resistivities Other Than 2.5 K·m/W to be Applied to the Current-Carrying Capacities for Reference Method D
(*Clause* S-3)

Thermal Resistivity, K·m/W	0.5	0.7	1	1.5	2	2.5	3
Correction Factor for Cables in Buried Ducts	1.28	1.20	1.18	1.1	1.05	1	0.96
Correction Factor for Direct Buried Cables	1.88	1.62	1.5	1.28	1.12	1	0.90

NOTES

1 The correction factors given have been averaged over the range of conductor sizes and types of installation included in Tables 21 to Table 24. The overall accuracy of correction factors is within 5 percent.

2 The correction factors are applicable to cables drawn into buried ducts; for cables laid direct in the ground the correction factors for thermal resistivities less than 2.5 K.m/W will be higher. Where more precise values are required they may be calculated by methods given in IEC 60287 series.

3 The correction factors are applicable to ducts buried at depths of up to 0.8 m.

4 It is assumed that the soil properties are uniform. No allowance had been made for the possibility of moisture migration which can lead to a region of high thermal resistivity around the cable. If partial drying out of the soil is foreseen, the permissible current rating should be derived by the methods specified in IEC 60287 series.

Table 36 Reduction Factors for one Circuit or One Multi-core Cable or for a Group of More Than One Circuit, or More Than One Multi-core Cable, to be Used with Current-Carrying Capacities of Table 21 to Table 32

(*Clauses* S-2.6, S-4 *and* S-6.2)

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Arrangement (Cables Touching)</th><th colspan="12">Number of Circuits or Multi-core Cables</th><th rowspan="2">To be Used with Current-Carrying Capacities, Reference</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>12</th><th>16</th><th>20</th></tr>
<tr><td>1</td><td>Bunched in air, on a surface, embedded or enclosed</td><td>1.00</td><td>0.80</td><td>0.70</td><td>0.65</td><td>0.60</td><td>0.57</td><td>0.54</td><td>0.52</td><td>0.50</td><td>0.45</td><td>0.41</td><td>0.38</td><td>Tables 21 to 32 Methods A to F</td></tr>
<tr><td>2</td><td>Single layer on wall, floor or unperforated cable tray systems</td><td>1.00</td><td>0.85</td><td>0.79</td><td>0.75</td><td>0.73</td><td>0.72</td><td>0.72</td><td>0.71</td><td>0.70</td><td colspan="3" rowspan="4">No further reduction factor for more than nine circuits or multicore cables</td><td rowspan="2">Tables 21 to 26 Method C</td></tr>
<tr><td>3</td><td>Single layer fixed directly under a wooden ceiling</td><td>0.95</td><td>0.81</td><td>0.72</td><td>0.68</td><td>0.66</td><td>0.64</td><td>0.63</td><td>0.62</td><td>0.61</td></tr>
<tr><td>4</td><td>Single layer on a perforated horizontal or vertical cable tray systems</td><td>1.00</td><td>0.88</td><td>0.82</td><td>0.77</td><td>0.75</td><td>0.73</td><td>0.73</td><td>0.72</td><td>0.72</td><td rowspan="2">Tables 27 to 32 Methods E and F</td></tr>
<tr><td>5</td><td>Single layer on cable ladder systems or cleats etc.,</td><td>1.00</td><td>0.87</td><td>0.82</td><td>0.80</td><td>0.80</td><td>0.79</td><td>0.79</td><td>0.78</td><td>0.78</td></tr>
</table>

NOTES

1 These factors are applicable to uniform groups of cables, equally loaded.

2 Where horizontal clearances between adjacent cables exceeds twice their overall diameter, no reduction factor need be applied.

3 The same factors are applied to:

– groups of two or three single-core cables;

– multi-core cables.

4 If a system consists of both two- and three-core cables, the total number of cables is taken as the number of circuits, and the corresponding factor is applied to the tables for two loaded conductors for the two-core cables, and to the tables for three loaded conductors for the three-core cables.

5 If a group consists of *n* single-core cables it may either be considered as *n*/2 circuits of two loaded conductors or *n*/3 circuits of three loaded conductors.

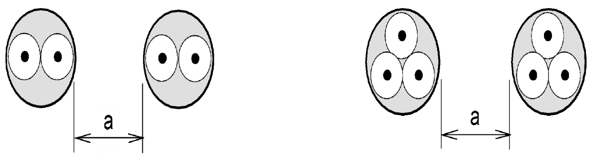
6 The values given have been averaged over the range of conductor sizes and types of installation included in Tables 21 to Table 32 the overall accuracy of tabulated values is within 5 percent.

7 For some installations and for other methods not provided for in the above table, it may be appropriate to use factors calculated for specific cases, see for example, Table 39 and Table 40.

Table 37 Reduction Factors for More Than One Circuit, Cables Laid Directly in the Ground – Installation Method D2 in Table 21 to Table 24 Single-Core or Multi-Core Cables
(*Clauses* 5.2.6.5, *and* S-4.1)

Number of Circuits	Cable to Cable Clearance				
	Nil (Cables Touching)	One Cable Diameter	0.125 m	0.25 m	0.5 m
2	0.75	0.80	0.85	0.90	0.90
3	0.65	0.70	0.75	0.80	0.85
4	0.60	0.60	0.70	0.75	0.80
5	0.55	0.55	0.65	0.70	0.80
6	0.50	0.55	0.60	0.70	0.80
7	0.45	0.51	0.59	0.67	0.76
8	0.43	0.48	0.57	0.65	0.75
9	0.41	0.46	0.55	0.63	0.74
12	0.36	0.42	0.51	0.59	0.71
16	0.32	0.38	0.47	0.56	0.38
20	0.29	0.35	0.44	0.53	0.66

a Multi-core cables



a Single-core cables

NOTES

1 Values given apply to an installation depth of 0.7 m and a soil thermal resistivity of 2.5 K·m/W. They are average values for the range of cable sizes and types quoted for Tables 21 to Table 24. The process of averaging, together with rounding off, can result in some cases in errors up to 10 %. (Where more precise values are required they may be calculated by methods given in IEC 60287-2-1).

2 In case of a thermal resistivity lower than 2.5 K·m/W the corrections factors can, in general, be increased and can be calculated by the methods given in IEC 60287-2-1.

3 If a circuit consists of *m* parallel conductors per phase, then for determining the reduction factor, this circuit should be considered as *m* circuits.

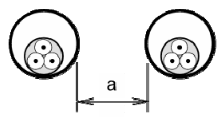
Table 38 Reduction Factors for More Than One Circuit, Cables Laid in Ducts in the Ground — Installation Method D1 in Table 20 to Table 24
(*Clauses* 5.2.6.5 *and* S-4.1)

A) Multi-Core Cables in Single-Way Ducts				
Number of Cables	Duct to Duct Clearance[a]			
	Nil (Ducts Touching)	0.25 m	0.5 m	1.0 m
2	0.85	0.90	0.95	0.95
3	0.75	0.85	0.90	0.95
4	0.70	0.80	0.85	0.90
5	0.65	0.80	0.85	0.90
6	0.60	0.80	0.80	0.90
7	0.57	0.76	0.80	0.88
8	0.54	0.74	0.78	0.88
9	0.52	0.73	0.77	0.87
10	0.49	0.72	0.76	0.86
11	0.47	0.70	0.75	0.86
12	0.45	0.69	0.74	0.85
13	0.44	0.68	0.73	0.85
14	0.42	0.68	0.72	0.84
15	0.41	0.67	0.72	0.84
16	0.39	0.66	0.71	0.83
17	0.38	0.65	0.70	0.83
18	0.37	0.65	0.70	0.83
19	0.35	0.64	0.69	0.82
20	0.34	0.63	0.68	0.82

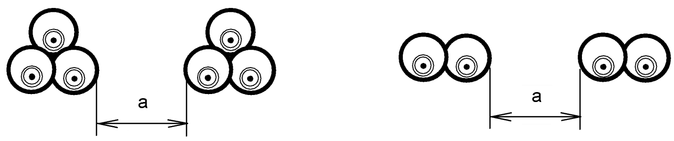
Table 38 — (*Concluded*)

B) Single-core Cables in Non-Magnetic Single-Way Ducts				
Number of Single-Core Circuits of Two or Three Cables	**Duct to Duct Clearance**			
	Nil (Ducts Touching)	0.25 m	0.5 m	1.0 m
2	0.80	0.90	0.90	0.95
3	0.70	0.80	0.85	0.90
4	0.65	0.75	0.80	0.90
5	0.60	0.70	0.80	0.90
6	0.60	0.70	0.80	0.90
7	0.53	0.66	0.76	0.87
8	0.50	0.63	0.74	0.87
9	0.47	0.61	0.73	0.86
10	0.45	0.59	0.72	0.85
11	0.43	0.57	0.70	0.85
12	0.41	0.56	0.69	0.84
13	0.39	0.54	0.68	0.84
14	0.37	0.53	0.68	0.83
15	0.35	0.52	0.67	0.83
16	0.34	0.51	0.66	0.83
17	0.33	0.50	0.65	0.82
18	0.31	0.49	0.65	0.82
19	0.30	0.48	0.64	0.82
20	0.29	0.47	0.63	0.81

[a] **Multi-core cables**



[b] **Single-core cables**



NOTES

1 Values given apply to an installation depth of 0.7 m and a soil thermal resistivity of 2.5 K·m/W. They are average values for the range of cable sizes and types quoted for Table 20 to Table 24. The process of averaging, together with rounding off, can result in some cases in errors up to 10 percent. Where more precise values are required they may be calculated by methods given in the IEC 60287series.

2 In case of a thermal resistivity lower than 2.5 K·m/W the corrections factors can, in general, be increased and can be calculated by the methods given in IEC 60287-2-1.

3 If a circuit consists of *n* parallel conductors per phase, then for determining the reduction factor this circuit shall be considered as *n* circuits.

Table 39 Reduction Factors for Group of More Than One Multi-core Cable to be Applied to Reference Current-Carrying Capacities for Multi-core Cables in Free Air — Method of Installation E in Table 27 to Table 32

(*Clause* 5.2.6.5)

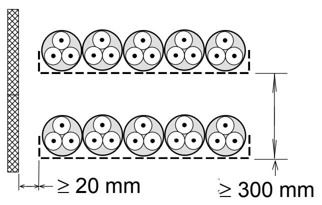
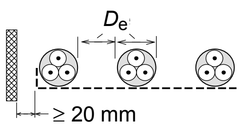
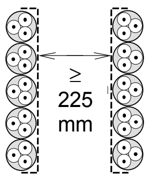
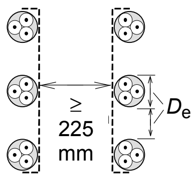
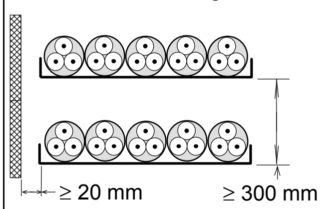
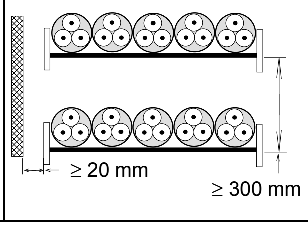
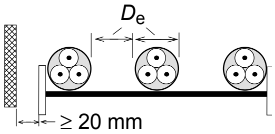
Method of Installation in Table 19			Number of Trays or Ladders	Number of Cables Per Tray or Ladder					
				1	2	3	4	6	9
Perforated cable tray systems (Note 3)	31	Touching 	1	1.00	0.88	0.82	0.79	0.76	0.73
			2	1.00	0.87	0.80	0.77	0.73	0.68
			3	1.00	0.86	0.79	0.76	0.71	0.66
			6	1.00	0.84	0.77	0.73	0.68	0.64
		Spaced 	1	1.00	1.00	0.98	0.95	0.91	–
			2	1.00	0.99	0.96	0.92	0.87	–
			3	1.00	0.98	0.95	0.91	0.85	–
Vertical perforated cable tray systems (Note 4)	31	Touching 	1	1.00	0.88	0.82	0.78	0.73	0.72
			2	1.00	0.88	0.81	0.76	0.71	0.70
		Spaced 	1	1.00	0.91	0.89	0.88	0.87	–
			2	1.00	0.91	0.88	0.87	0.85	–
Unperforated cable tray systems	31	Touching 	1	0.97	0.84	0.78	0.75	0.71	0.68
			2	0.97	0.83	0.76	0.72	0.68	0.63
			3	0.97	0.82	0.75	0.71	0.66	0.61
			6	0.97	0.81	0.73	0.69	0.63	0.58
Cable ladder systems, cleats, etc (Note 3)	32 33 34	Touching 	1	1.00	0.87	0.82	0.80	0.79	0.78
			2	1.00	0.86	0.80	0.78	0.76	0.73
			3	1.00	0.85	0.79	0.76	0.73	0.70
			6	1.00	0.84	0.77	0.73	0.68	0.64

Table 39 — (*Concluded*)

Method of Installation in Table 19			Number of Trays or Ladders	Number of Cables Per Tray or Ladder					
				1	2	3	4	6	9
		Spaced 	1 2 3	1.00 1.00 1.00	1.00 0.99 0.98	1.00 0.98 0.97	1.00 0.97 0.96	1.00 0.96 0.93	– – –

NOTES

1 Values given are averages for the cable types and range of conductor sizes considered in Tables 27 to Table 32. The spread of values is generally less than 5 percent.

2 Factors apply to single layer groups of cables as shown above and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and has to be determined by an appropriate method.

3 Values are given for vertical spacing between cable trays of 300 mm and at least 20 mm between cable trays and wall. For closer spacing the factors should be reduced.

4 Values are given for horizontal spacing between cable trays of 225 mm with cable trays mounted back to back. For closer spacing the factors should be reduced.

Table 40 Reduction Factors for Groups of One or More Circuits of Single-core Cables to be Applied to Reference Current-Carrying Capacity for One Circuit of Single-Core Cables in Free Air — Method of Installation F in Table 27 to Table 32

(*Clause* 5.2.6.5)

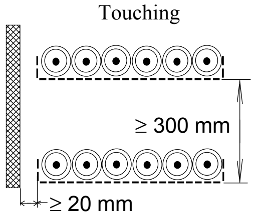
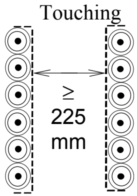
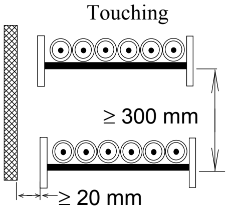
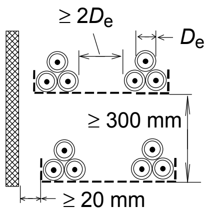
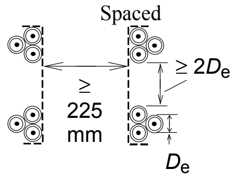
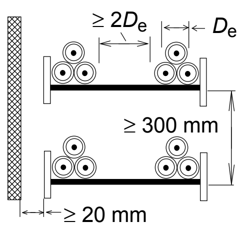
Method of Installation in Table 19			Number of Trays or Ladders	Number of Three-Phase Circuits Per Tray or Ladder			Use as a Multiplier to Current-Carrying Capacity for
				1	2	3	
Perforated cable tray systems (Note 3)	31	Touching 	1 2 3	0.98 0.96 0.95	0.91 0.87 0.85	0.87 0.81 0.78	Three cables in horizontal formation
Vertical perforated cable tray systems (Note 4)	31	Touching 	1 2	0.96 0.95	0.86 0.84	– –	Three cables in vertical formation
Cable ladder systems, cleats, etc (Note 3)	32 33 34	Touching 	1 2 3	1.00 0.98 0.97	0.97 0.93 0.90	0.96 0.89 0.86	Three cables in horizontal formation

Table 40 — (*Concluded*)

<table>
<tr><th colspan="3" rowspan="2">Method of Installation in Table 19</th><th rowspan="2">Number of Trays or Ladders</th><th colspan="3">Number of Three-Phase Circuits Per Tray or Ladder</th><th rowspan="2">Use as a Multiplier to Current-Carrying Capacity for</th></tr>
<tr><th>1</th><th>2</th><th>3</th></tr>
<tr><td>Perforated cable tray systems (Note 3)</td><td>31</td><td>
</td><td>1
2
3</td><td>1.00
0.97
0.96</td><td>0.98
0.93
0.92</td><td>0.96
0.89
0.86</td><td rowspan="3">Three cables in trefoil formation</td></tr>
<tr><td>Vertical perforated cable tray systems (Note 4)</td><td>31</td><td>
</td><td>1
2</td><td>1.00
1.00</td><td>0.91
0.90</td><td>0.89
0.86</td></tr>
<tr><td>Cable ladder systems, cleats, etc (Note 3)</td><td>32
33
34</td><td>
</td><td>1
2
3</td><td>1.00
0.97
0.96</td><td>1.00
0.95
0.94</td><td>1.00
0.93
0.90</td></tr>
</table>

NOTES

1 Values given are averages for the cable types and range of conductor sizes considered in Table 27 to Table 32. The spread of values is generally less than 5 percent.

2 Factors are given for single layers of cables (or trefoil groups) as shown in the table and do not apply when cables are installed in more than one layer touching each other. Values for such installations may be significantly lower and should be determined by an appropriate method.

3 Values are given for vertical spacing between cable trays of 300 mm and at least 20 mm between cable trays and wall. For closer spacing the factors should be reduced.

4 Values are given for horizontal spacing between cable trays of 225 mm with cable trays mounted back to back. For closer spacing the factors should be reduced.

5 For circuits having more than one cable in parallel per phase, each three phase set of conductors should be considered as a circuit for the purpose of this table.

6 If a circuit consists of *m* parallel conductors per phase, then for determining the reduction factor this circuit should be considered as *m* circuits.

ANNEX T

(*Normative*)

EXAMPLE OF A METHOD OF SIMPLIFICATION OF THE TABLES OF 5.2.6

This Annex is intended to illustrate one possible method by which the Table 21 to Table 24, Table 29 to Table 32 and Table 36 to Table 40 can be simplified for adoption.

The use of other suitable methods is not excluded (*see* Note of **5.2.6.2**).

Table 41 Current-Carrying Capacity in Amperes

Reference Methods in Table 20	**Number of Loaded Conductors and type of Insulation**											
A1		3 PVC	2 PVC		3 XLPE	2 XLPE						
A2	3 PVC	2 PVC		3 XLPE	2 XLPE							
B1				3 PVC	2 PVC		3 XLPE		2 XLPE			
B2			3 PVC	2 PVC		3 XLPE	2 XLPE					
C					3 PVC		2 PVC	3 XLPE		2 XLPE		
E						3 PVC		2 PVC	3 XLPE		2 XLPE	
F							3 PVC		2 PVC	3 XLPE		2 XLPE
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Size (mm^2) Copper												
1.5	13	13.5	14.5	15.5	17	18.5	19.5	22	23	24	26	–
2.5	17.5	18	19.5	21	23	25	27	30	31	33	36	–
4	23	24	26	28	31	34	36	40	42	45	49	–
6	29	31	34	36	40	43	46	51	54	58	63	–
10	39	42	46	50	54	60	63	70	75	80	86	–
16	52	56	61	68	73	80	85	94	100	107	115	–
25	68	73	80	89	95	101	110	119	127	135	149	161
35	–	–	–	110	117	126	137	147	158	169	185	200
50	–	–	–	134	141	153	167	179	192	207	225	242
70	–	–	–	171	179	196	213	229	246	268	289	310
95	–	–	–	207	216	238	258	278	298	328	352	377
120	–	–	–	239	249	276	299	322	346	382	410	437
150	–	–	–	–	285	318	344	371	395	441	473	504
185	–	–	–	–	324	362	392	424	450	506	542	575
240	–	–	–	–	380	424	461	500	538	599	641	679
Aluminium												
2.5	13.5	14	15	16.5	18.5	19.5	21	23	24	26	28	–
4	17.5	18.5	20	22	25	26	28	31	32	35	38	–
6	23	24	26	28	32	33	36	39	42	45	49	–
10	31	32	36	39	44	46	49	54	58	62	67	–
16	41	43	48	53	58	61	66	73	77	84	91	–
25	53	57	63	70	73	78	83	90	97	101	108	121
35	–	–	–	86	90	96	103	112	120	126	135	150
50	–	–	–	104	110	117	125	136	146	154	164	184
70	–	–	–	133	140	150	160	174	187	198	211	237
95	–	–	–	161	170	183	195	211	227	241	257	289
120	–	–	–	186	197	212	226	245	263	280	300	337
150	–	–	–	–	226	245	261	283	304	324	346	389
185	–	–	–	–	256	280	298	323	347	371	397	447
240	–	–	–	–	300	330	352	382	409	439	470	530

NOTE — The appropriate table of current-carrying capacity given in Annex S should be consulted to determine the range of conductor sizes for which the above current-carrying capacities are applicable, for each installation method.

Table 42 Current-Carrying Capacities in Amperes

Installation Method	Size	Number of Loaded Conductors and Type of Insulation			
	mm^2	2 PVC	3 PVC	2 XLPE	3 XLPE
	Copper				
	1.5	22	18	26	22
	2.5	29	24	34	29
	4	38	31	44	37
	6	47	39	56	46
	10	63	52	73	61
	16	81	67	95	79
	25	104	86	121	101
D1/D2	35	125	103	146	122
	50	148	122	173	144
	70	183	151	213	178
	95	216	179	252	211
	120	246	203	287	240
	150	278	230	324	271
	185	312	258	363	304
	240	361	297	419	351
	300	408	336	474	396
	Aluminium				
	2.5	22	18.5	26	22
	4	29	24	34	29
	6	36	30	42	36
	10	48	40	56	47
	16	62	52	73	61
	25	80	66	93	78
	35	96	80	112	94
D1/D2	50	113	94	132	112
	70	140	117	163	138
	95	166	138	193	164
	120	189	157	220	186
	150	213	178	249	210
	185	240	200	279	236
	240	277	230	322	272
	300	313	260	364	308

Table 43 Reduction Factors for Groups of Several Circuits or of Several Multi-core Cables (to be Used with Current-Carrying Capacities of Table 41)

Item	Arrangement	Number of Circuits or Multi-core Cables								
		1	2	3	4	6	9	12	16	20
1	Bunched in air, on a surface, embedded or enclosed	1.00	0.80	0.70	0.65	0.55	0.50	0.45	0.40	0.40
2	Single layer on walls, floors or on unperforated trays	1.00	0.85	0.80	0.75	0.70	0.70	–	–	–
3	Single layer fixed directly under a ceiling	0.95	0.80	0.70	0.70	0.65	0.60	–	–	–
4	Single layer on perforated horizontal trays or on vertical trays	1.00	0.90	0.80	0.75	0.75	0.70	–	–	–
5	Single layer on cable ladder supports or cleats, etc.	1.00	0.85	0.80	0.80	0.80	0.80	–	–	–

ANNEX U

(*Clause* 5.2)

(*Normative*)

FORMULAE TO EXPRESS CURRENT-CARRYING CAPACITIES

The values given in Table 21 to Table 32 lie on smooth curves relating current-carrying capacity to cross-sectional area of conductor.

These curves can be derived using the following formulae:

$$I = a \times s^{m} - b \times s^{n}$$

where

I = the current-carrying capacity, in amperes;

S = the nominal cross-sectional area of conductor, in square millimetres [(mm)^2][1)]

a and b are coefficients and m and n are exponents according to cable and method of installation.

Values of the coefficients and exponents are given in the accompanying table. Current-carrying capacities should be rounded off to the nearest 0.5 A for values not exceeding 20 A and to the nearest ampere for values greater than 20 A.

The number of significant figures obtained is not to be taken as an indication of the accuracy of the current-carrying capacity.

For practically all cases, only the first term is needed. The second term is needed in only eight cases where large single-core cables are used.

It is not advisable to use these coefficients and exponents for conductor sizes outside the appropriate range used in Table 21 to Table 32.

[1)] Where the nominal size is 50 mm^2, for cables with extruded insulation, the value of 47.5 mm^2 should be used. For all other sizes and for all sizes of mineral insulated cables the nominal value is sufficiently precise.

Table 44 Table of Coefficients and Exponents

Current-Carrying Capacity Table	Column	Copper Conductor		Aluminium Conductor	
		a	*m*	*a*	*m*
21	2	11.2	0.611 8	8.61	0.616
	3 ($s \leq 120$ mm^2)	10.8	0.601 5	8.361	0.602 5
	3 ($s > 120$ mm^2)	10.19	0.611 8	7.84	0.616
	4	13.5	0.625	10.51	0.625 4
	5	13.1	0.600	10.24	0.599 4
	6 $\leq$ 16 mm^2	15.0	0.625	11.6	0.625
	6 $>$ 16 mm^2	15.0	0.625	10.55	0.640
	7	17.42	0.540	13.6	0.540
22	2	14.9	0.611	11.6	0.615
	3(s) $\leq$ 120 mm^2	14.46	0.598	11.26	0.602
	3(s) $>$ 120 mm^2	13.56	0.611	10.56	0.615
	4	17.76	0.625 0	13.95	0.627
	5	17.25	0.600	13.5	0.603
	6 $\leq$ 16 mm^2	18.77	0.628	14.8	0.625
	6 $>$ 16 mm^2	17.0	0.650	12.6	0.648
	7	20.25	0.542	15.82	0.541
23	2	10.4	0.605	7.94	0.612
	3(s) $\leq$ 120 mm^2	10.1	0.592	7.712	0.598 4
	3(s) $>$ 120 mm^2	9.462	0.605	7.225	0.612
	4	11.84	0.628	9.265	0.627
	5	11.65	0.600 5	9.03	0.601
	6 $\leq$ 16 mm^2	13.5	0.625	10.5	0.625
	6 $>$16 mm^2	12.4	0.635	9.536	0.632 4
	7	14.34	0.542	11.2	0.542
24	2	13.34	0.611	10.9	0.605
	3(s) $\leq$ 120 mm^2	12.95	0.598	10.58	0.592
	3(s) $>$ 120 mm^2	12.14	0.611	9.92	0.605
	4	15.62	0.625 2	12.3	0.630
	5	15.17	0.60	11.95	0.605
	6 $\leq$ 16 mm^2	17.0	0.623	13.5	0.625
	6 $>$ 16 mm^2	15.4	0.635	11.5	0.639
	7	16.88	0.539	13.2	0.539
		Coefficients and exponents			
		a	*m*	*b*	*n*
25	500 V 2	18.5	0.56	–	–
	3	14.9	0.612	–	–
	4	16.8	0.59	–	–
	750 V 2	19.6	0.596	–	–
	3	16.24	0.599 5	–	–
	4	18.0	0.59	–	–
26	500 V 2	22.0	0.60	–	–
	3	19.0	0.60	–	–
	4	21.2	0.58	–	–
	750 V 2	24.0	0.60	–	–
	3	20.3	0.60	–	–
	4	23.88	0.579 4	–	–
27	500 V 2	19.5	0.58	–	–
	3	16.5	0.58	–	–
	4	18.0	0.59	–	–
	5	20.2	0.58	–	–
	6	23.0	0.58	–	–

NOTE — *a*, *b* are coefficients and *m*, *n* are exponents.

Table 44 — (*Concluded*)

Current-Carrying Capacity Table	Column	Copper Conductor		Aluminium Conductor	
		a	*m*	*a*	*m*
27	750 V 2	20.6	0.60	–	–
	3	17.4	0.60	–	–
	4	20.15	0.584 5	–	–
	5 ≤ 120 mm^2	22.0	0.58	–	–
	5 > 120 mm^2	22.0	0.58	1 - 10–11	5.25
	6 ≤ 120 mm^2	25.17	0.578 5	–	–
	6 > 120 mm^2	25.17	0.578 5	1.9 - 10–11	5.15
	500 V 2	24.2	0.58	–	–
	3	20.5	0.58	–	–
	4	23.0	0.57	–	–
	5	26.1	0.549	–	–
	6	29.0	0.57	–	–
28	750 V 2	26.04	0.599 7	–	–
	3	21.8	0.60	–	–
	4	25.0	0.585	–	–
	5 ≤ 120 mm^2	27.55	0.579 2	–	–
	5 > 120 mm^2	27.55	0.579 2	1.3 - 10–10	4.8
	6 ≤ 120 mm^2	31.58	0.579 1	–	–
	6 > 120 mm^2	31.58	0.579 1	1.8 - 10–7	3.55
	2 ≤ 16 mm^2	16.8	0.62	–	–
	2 > 16 mm^2	14.9	0.646	–	–
	3 ≤ 16 mm^2	14.30	0.62	–	–
	3 > 16 mm^2	12.9	0.64	–	–
	4	17.1	0.632	–	–
29	5 ≤ 300 mm^2	13.28	0.656 4	–	–
	5 > 300 mm^2	13.28	0.656 4	6 - 10–5	2.14
	6 ≤ 300 mm^2	13.75	0.658 1	–	–
	6 > 300 mm^2	13.75	0.658 1	1.2 - 10–4	2.01
	7	18.75	0.637	–	–
	8	15.8	0.654	–	–
	2 ≤ 16 mm^2	12.8	0.627	–	–
	2 > 16 mm^2	11.4	0.64	–	–
	3 ≤ 16 mm^2	11.0	0.62	–	–
	3 > 16 mm^2	9.9	0.64	–	–
30	4	12.0	0.653	–	–
(aluminium conductors)	5	9.9	0.663	–	–
	6	10.2	0.666	–	–
	7	13.9	0.647	–	–
	8	11.5	0.668	–	–
	2 ≤ 16 mm^2	20.5	0.623	–	–
	2 > 16 mm^2	18.6	0.646	–	–
	3 ≤ 16 mm^2	17.8	0.623	–	–
	3 > 16 mm^2	16.4	0.637	–	–
	4	20.8	0.636	–	–
31	5 ≤ 300 mm^2	16.0	0.6633	–	–
	5 > 300 mm^2	16.0	0.6633	6 - 10–4	1.793
	6 ≤ 300 mm^2	16.57	0.665	–	–
	6 > 300 mm^2	16.57	0.665	3 - 10–4	1.876
	7	22.9	0.644	–	–
	8	19.1	0.662	–	–
	2 ≤ 16 mm^2	16.0	0.625	–	–
	2 > 16 mm^2	13.4	0.649	–	–
	3 ≤ 16 mm^2	13.7	0.623	–	–
	3 > 16 mm^2	12.6	0.635	–	–
32	4	14.7	0.654	–	–
(aluminium conductors)	5	11.9	0.671	–	–
	6	12.3	0.673	–	–
	7	16.5	0.659	–	–
	8	13.8	0.676	–	–
				–	–

ANNEX V

(*Clause* 5.2.6.6.3)

(*Normative*)

EFFECT OF HARMONIC CURRENTS ON BALANCED THREE-PHASE SYSTEMS

V-1 REDUCTION FACTORS FOR HARMONIC CURRENTS IN FOUR-CORE AND FIVE-CORE CABLES WITH FOUR CORES CARRYING CURRENT

The subclause **5.2.6.6.3** states that where the neutral conductor carries current without a corresponding reduction in load of the line conductors, the current flowing in the neutral conductor shall be taken into account in ascertaining the current-carrying capacity of the circuit.

This Annex is intended to cover the situation where there is current flowing in the neutral of a balanced three-phase system. Such neutral currents are due to the line currents having a harmonic content which does not cancel in the neutral. The most significant harmonic which does not cancel in the neutral is usually the third harmonic. The magnitude of the neutral current due to the third harmonic may exceed the magnitude of the power frequency line current. In such a case, the neutral current will have a significant effect on the current-carrying capacity of the cables in the circuit.

The reduction factors given in this Annex apply to balanced three-phase circuits; it is recognized that the situation is more onerous if only two of the three phases are loaded. In this situation, the neutral conductor will carry the harmonic currents in addition to the unbalanced current. Such a situation can lead to overloading of the neutral conductor.

Equipment likely to cause significant harmonic currents are, for example, fluorescent lighting banks and d.c. power supplies such as those found in computers. Further information on harmonic disturbances can be found in the IEC 61000 series.

The reduction factors given in Table 45 only apply to cables where the neutral conductor is within a four-core or five-core cable and is of the same material and cross-sectional area as the line conductors. These reduction factors have been calculated based on third harmonic currents.

If significant, that is, more than 15 percent, higher harmonics, for example, 9th, 12th, etc are expected then lower reduction factors are applicable. Where there is an unbalance between phases of more than 50 percent then lower reduction factors may be applicable.

The tabulated reduction factors, when applied to the current-carrying capacity of a cable with three loaded conductors, will give the current-carrying capacity of a cable with four loaded conductors where the current in the fourth conductor is due to harmonics. The reduction factors also take the heating effect of the harmonic current in the line conductors into account.

Where the neutral current is expected to be higher than the line current then the cable size should be selected on the basis of the neutral current.

Where the cable size selection is based on a neutral current which is not significantly higher than the line current it is necessary to reduce the tabulated current-carrying capacity for three loaded conductors.

If the neutral current is more than 135 percent of the line current and the cable size is selected on the basis of the neutral current, then the three line conductors will not be fully loaded. The reduction in heat generated by the line conductors offsets the heat generated by the neutral conductor to the extent that it is not necessary to apply any reduction factor to the current-carrying capacity for three loaded conductors.

NOTE — The third harmonic content of the line current is the ratio of the third harmonic and the fundamental (first harmonic), expressed in percent.

Table 45 Reduction Factors for Harmonic Currents in Four-Core and Five-Core Cables

Third Harmonic Content of Line Current %	Reduction Factor	
	Size Selection is Based Line on Current	Size Selection is Based on Neutral Current
0–15	1.0	–
15–33	0.86	–
33–45	–	0.86
45	–	1.0

V-2 EXAMPLES OF THE APPLICATION OF REDUCTION FACTORS FOR HARMONIC CURRENTS

Consider a three-phase circuit with a design load of 39 A to be installed using four-core PVC insulated cable clipped to a wall, installation method C.

From Table 23, a 6 mm^2 cable with copper conductors has a current-carrying capacity of 41 A and hence is suitable if harmonics are not present in the circuit.

If 20 percent third harmonic is present, then a

reduction factor of 0.86 is applied and the design load becomes:

$$\frac{39}{0.86} = 45\text{A}$$

For this load, a 10 mm^2 cable is necessary.

If 40 percent third harmonic is present, the cable size selection is based on the neutral current which is:

$$39 \times 0.4 \times 3 = 46.8\ \text{A}$$

and a reduction factor of 0.86 is applied, leading to a design load of:

$$\frac{46.8}{0.86} = 54.4\text{A}$$

For this load a 10 mm^2 cable is suitable.

If 50 per cent third harmonic is present, the cable size is again selected on the basis of the neutral current, which is:

$$39 \times 0.5 \times 3 = 58.5\ \text{A}$$

In this case, the reduction factor is 1 and a 16 mm^2 cable is required.

All the above cable selections are based on the current-carrying capacity of the cable; voltage drop and other aspects of design have not been considered.

ANNEX W

(*Clause* 5.2.4.6)

(*Normative*)

SELECTION OF CONDUIT SYSTEMS

Guidance on the selection of conduit systems is given in Table 46.

Table 46 Suggested Characteristics for Conduit
(classification according to IS 14930 Part 1 & Part 2)

<table>
<tr><th colspan="3">Situation</th><th>Resistance to Compression</th><th>Resistance to Impact</th><th>Minimum Operating Temperature</th><th>Maximum Operating Temperature</th></tr>
<tr><td>Outdoor installation</td><td colspan="2">Exposed installation</td><td>3</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td rowspan="8">Indoors use</td><td colspan="2">Exposed installation</td><td>2</td><td>2</td><td>2</td><td>1</td></tr>
<tr><td colspan="2">Under floor installations (floor screed)</td><td>2</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td rowspan="5">Embedded</td><td>Concrete</td><td>3</td><td>3</td><td>2</td><td>1</td></tr>
<tr><td>Hollow wall/on wood (inflammable material)</td><td rowspan="4">2</td><td rowspan="4">2</td><td rowspan="4">2</td><td rowspan="4">1</td></tr>
<tr><td>In masonry</td></tr>
<tr><td>Building voids</td></tr>
<tr><td>Ceiling voids</td></tr>
<tr><td colspan="2">Overhead mounting</td><td>4</td><td>3</td><td>3</td><td>1</td></tr>
</table>

NOTES

1 These values are only a sample of the characteristics for conduit given in IS 14930 (Parts 1 & 2).

2 According to resistance to flame propagation, conduit systems of orange colour are only permitted when embedded in concrete. For other methods for installation all colours are permitted with the exception of yellow, orange or red.

ANNEX Y

(*Clause* 5.2)
(*Normative*)

VOLTAGE DROP IN CONSUMERS' INSTALLATIONS

Y-1 MAXIMUM VALUE OF VOLTAGE DROP

The voltage drop between the origin of an installation and any load point should not be greater than the values in Table 47 expressed with respect to the value of the nominal voltage of the installation

NOTES

1 A greater voltage drop may be accepted
– for motor during starting periods,
– for other equipment with high inrush current,
provided that in both cases it is ensured that the voltage variations remains within the limits specified in the relevant equipment standard.

2 The following temporary conditions are excluded:
– voltage transients;
–voltage variation due to abnormal operation.

Table 47 Voltage Drop

Type of Installation	Lighting %	Other Uses %
A – Low voltage installations supplied directly from a public low voltage distribution system	3	5
B – Low voltage installation supplied from private LV supply[1)]	6	8

[1)] As far as possible, it is recommended that voltage drop within the final circuits do not exceed those indicated in installation type A.

When the main wiring systems of the installations are longer than 100 m, these voltage drops may be increased by 0.005 percent per metre of wiring system beyond 100 m, without this supplement being greater than 0.5 percent.

Voltage drop is determined from the demand by the current-using equipment, applying diversity factors where applicable, or from the values of the design current of the circuits.

Voltage drops may be determined using the following formula:

$$u = b\left(\rho_1 \frac{L}{S}\cos\varphi + \lambda L \sin\varphi\right) I_B$$

where

u = the voltage drop in V;

b = the coefficient equal to 1 for three-phases circuits, and equal to 2 for single-phase circuits;

NOTE — Three-phase circuits with the neutral completely unbalanced (a single phase loaded) are considered a single-phase circuits.

ρ_1 = the resistivity of conductors in normal service, taken equal to the resistivity at the temperature in normal service, that is, 1.25 times the resistivity at 20 °C, or 0.0225 $\Omega mm^2/m$ for copper and 0.036 $\Omega mm^2/m$ for aluminium;

L = the straight length of the wiring systems, in m

S = the cross-sectional area of conductors, in mm^2;

cos ϕ = the power factor; in the absence of precise details, the power factor is taken as equal to 0.8 (sin ϕ = 0.6);

λ = the reactance per unit length of conductors, which is taken to be 0.08 mΩ/m in the absence of other details;

I_B = the design current (in amps)

The relevant voltage drop in per cent is equal to:

$$\Delta u = 100 \frac{u}{U_0}$$

U_0 = the voltage between line and neutral, in volts.

NOTE — In extra-low voltage circuits, it is not necessary to fulfil the voltage drop limits of Table 47 for uses other than lighting (for example, bell, control, door opening, etc.), provided that a check is made that the equipment is operating correctly.

ANNEX Z

(*Clause* 5.2.6.7)
(*Informative*)

EXAMPLES OF CONFIGURATIONS OF PARALLEL CABLES

The special configurations referred in **5.2.6.7** can be:

a) for 4 three-core cables the connection scheme: $L_1L_2L_3$, $L_1L_2L_3$, $L_1L_2L_3$, $L_1L_2L_3$; the cables may be touching;

b) for 6 single-core cables
   1) in a flat plane, *see* Fig. 78,
   2) above each other, *see* Fig. 79,
   3) in trefoil, *see* Fig. 80;

c) for 9 single-core cables
   1) in a flat plane, *see* Fig. 81,
   2) above each other, *see* Fig. 82,
   3) in trefoil, *see* Fig. 83;

d) for 12 single-core cables
   1) in a flat plane, *see* Fig. 84,
   2) above each other, *see* Fig. 85,
   3) in trefoil, *see* Fig. 86.

The distances in these figures shall be maintained.

NOTE — Where possible, the impedance differences between the phases are also limited in the special configurations.

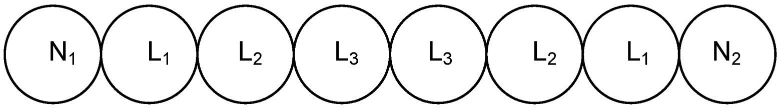


FIG. 78 SPECIAL CONFIGURATION FOR 6 PARALLEL SINGLE-CORE CABLES IN A FLAT PLANE (*see* **5.2.6.7**)

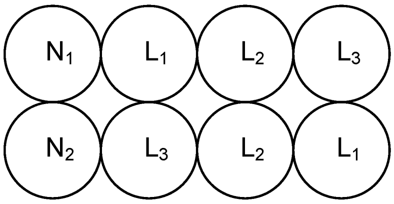


FIG. 79 SPECIAL CONFIGURATION FOR 6 PARALLEL SINGLE-CORE CABLES ABOVE EACH OTHER (*see* **5.2.6.7**)

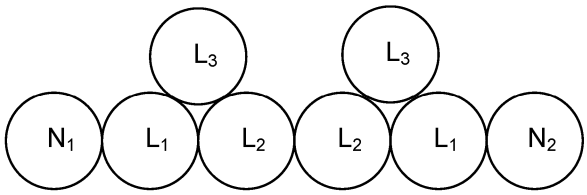
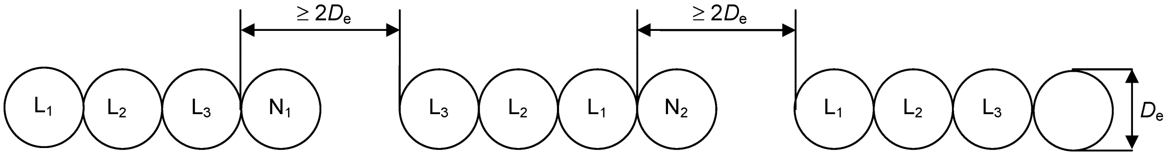


FIG. 80 SPECIAL CONFIGURATION FOR 6 PARALLEL SINGLE-CORE CABLES IN TREFOIL (*see* **5.2.6.7**)



NOTE — D_e is the outer diameter of the cable.

FIG. 81 SPECIAL CONFIGURATION FOR 9 PARALLEL SINGLE-CORE CABLES IN A FLAT PLANE (*see* **5.2.6.7**)

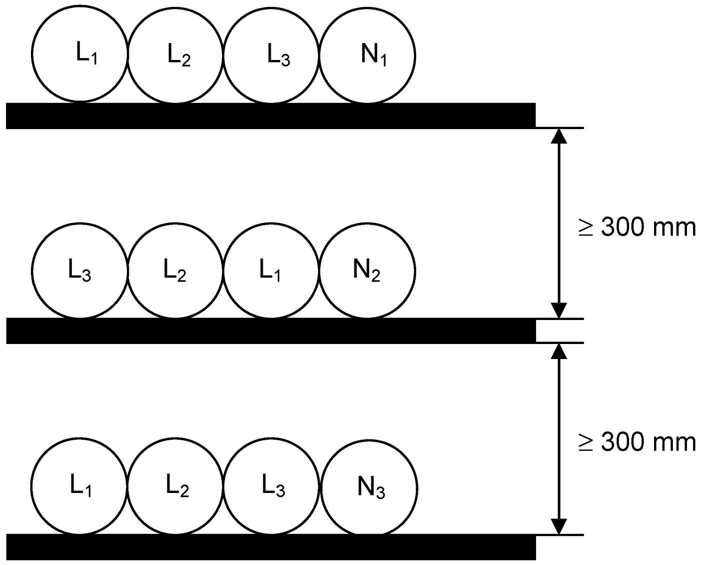
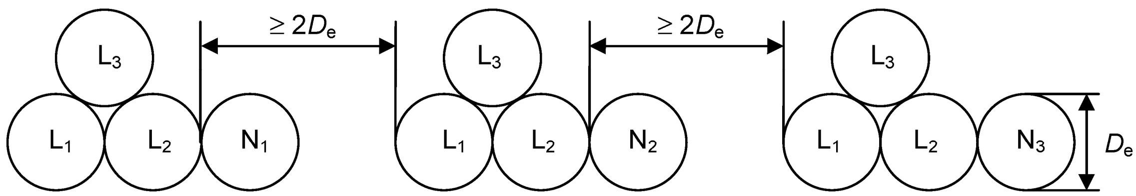


FIG. 82 SPECIAL CONFIGURATION FOR 9 PARALLEL SINGLE-CORE CABLES ABOVE EACH OTHER (*see* **5.2.6.7**)



NOTE — D_e is the outer diameter of the cable.

FIG. 83 SPECIAL CONFIGURATION FOR 9 PARALLEL SINGLE-CORE CABLES IN TREFOIL (*see* **5.2.6.7**)

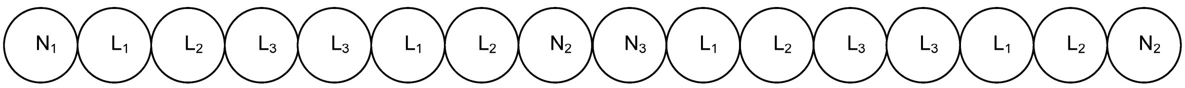


FIG. 84 SPECIAL CONFIGURATION FOR 12 PARALLEL SINGLE-CORE CABLES IN A FLAT PLANE (*see* **5.2.6.7**)

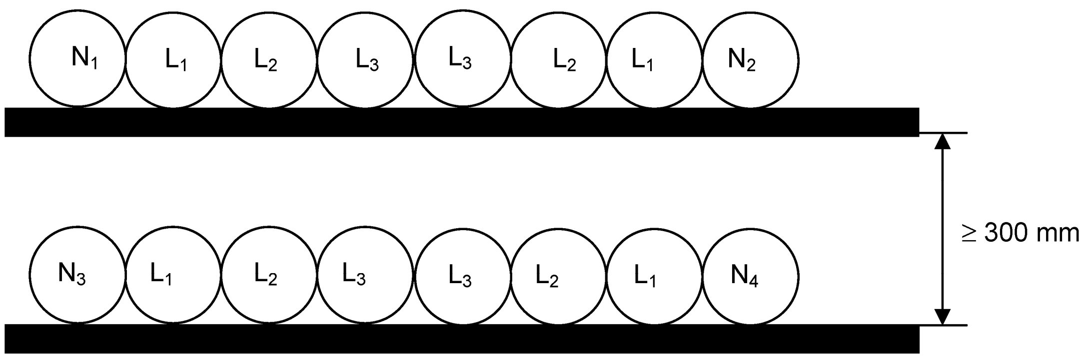


FIG. 85 SPECIAL CONFIGURATION FOR 12 PARALLEL SINGLE-CORE CABLES ABOVE EACH OTHER (*see* **5.2.6.7**)

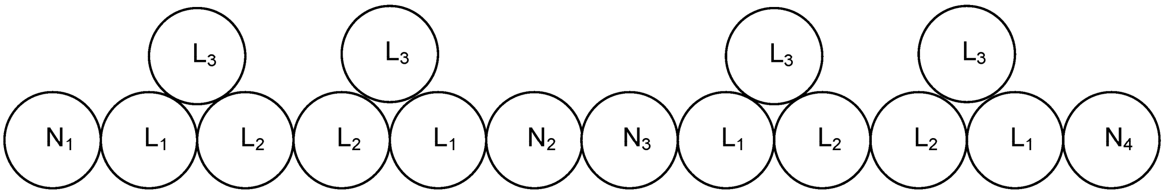


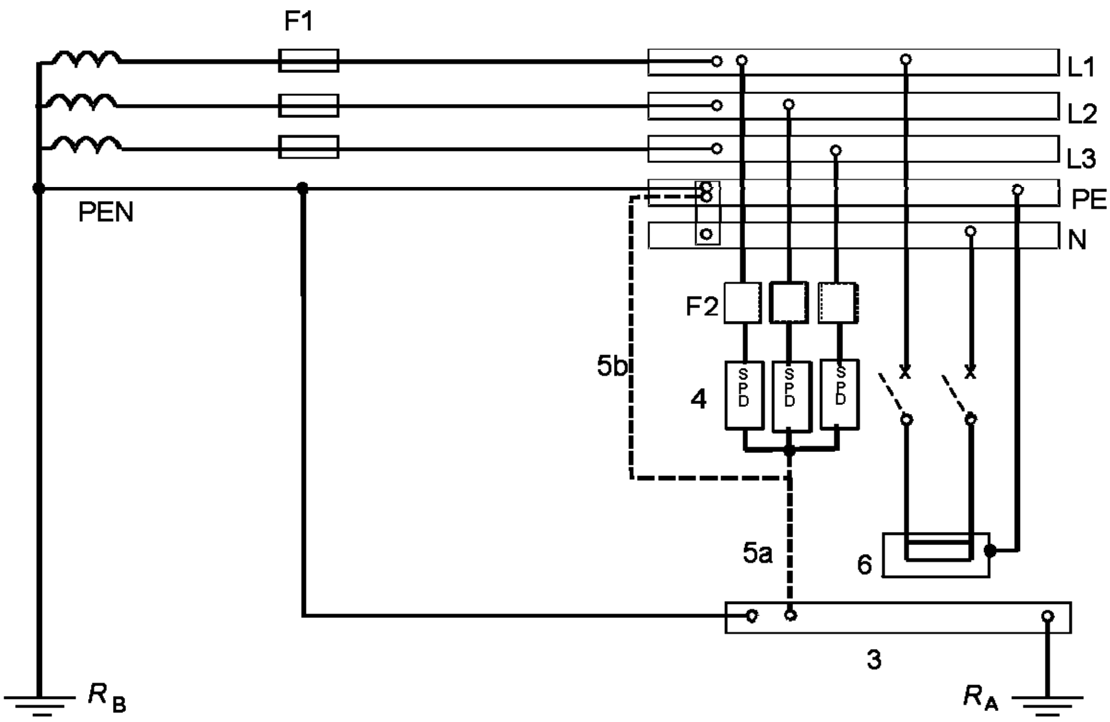
FIG. 86 SPECIAL CONFIGURATION FOR 12 PARALLEL SINGLE-CORE CABLES IN TREFOIL (*see* **5.2.6.7**)

ANNEX AA

(*Clause* 5.3)

(*Normative*)

INSTALLATION OF SURGE PROTECTIVE DEVICES IN TN SYSTEMS



3 — Main earthing terminal or bar

4 — Surge protective devices providing protection against overvoltages of category II

5 — Earthing connection of surge protective devices, either 5a or 5b

6 — Equipment to be protected

*F*1 — Protective device at the origin of the installation

*F*2 — Protective device required by the manufacturer of the SPD

R_A — Earthing electrode (earthing resistance) of the installation

R_B — Earthing electrode (earthing resistance) of the supply system

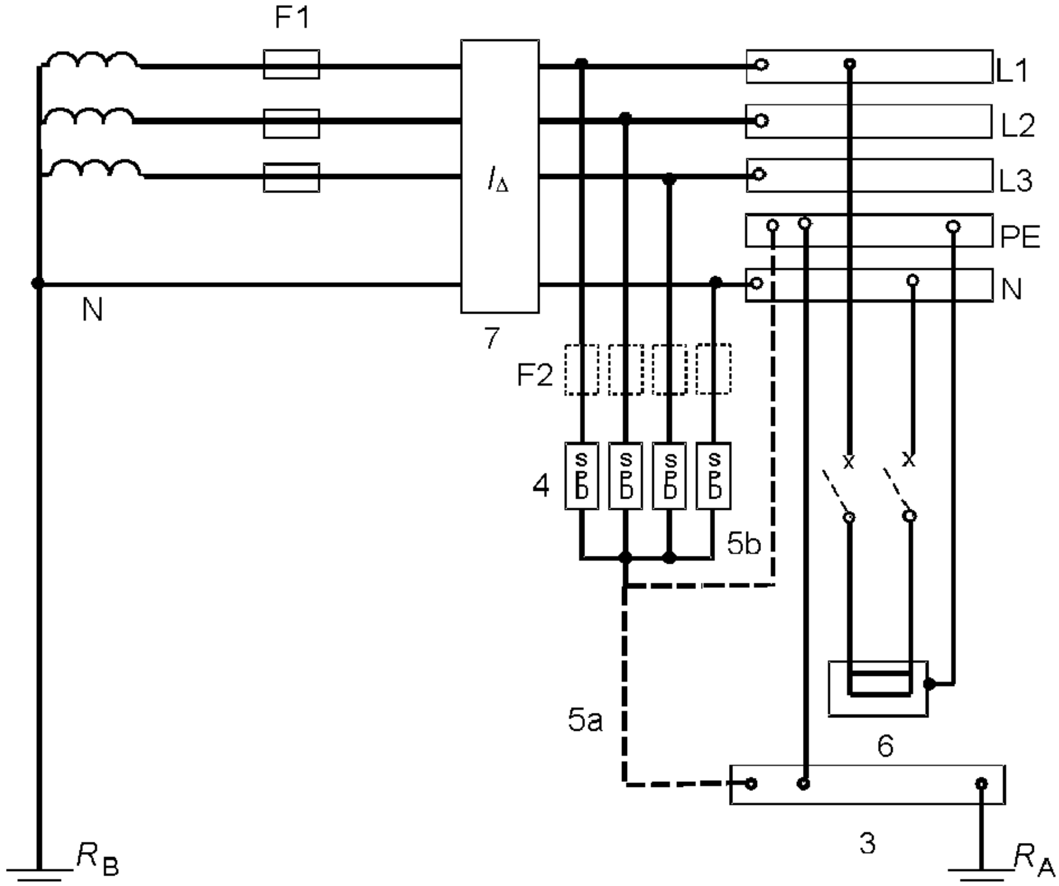
FIG. 87 SPDS IN TN SYSTEMS

ANNEX BB

(*Clause* 5.3)

(*Normative*)

INSTALLATION OF SURGE PROTECTIVE DEVICES IN TT SYSTEMS



3 — Main earthing terminal or bar

4 — Surge protective devices providing protection against overvoltages of category II

5 — Earthing connection of surge protective devices, either 5a and/or 5b

6 — Equipment to be protected

7 — Residual current protective device (RCD)

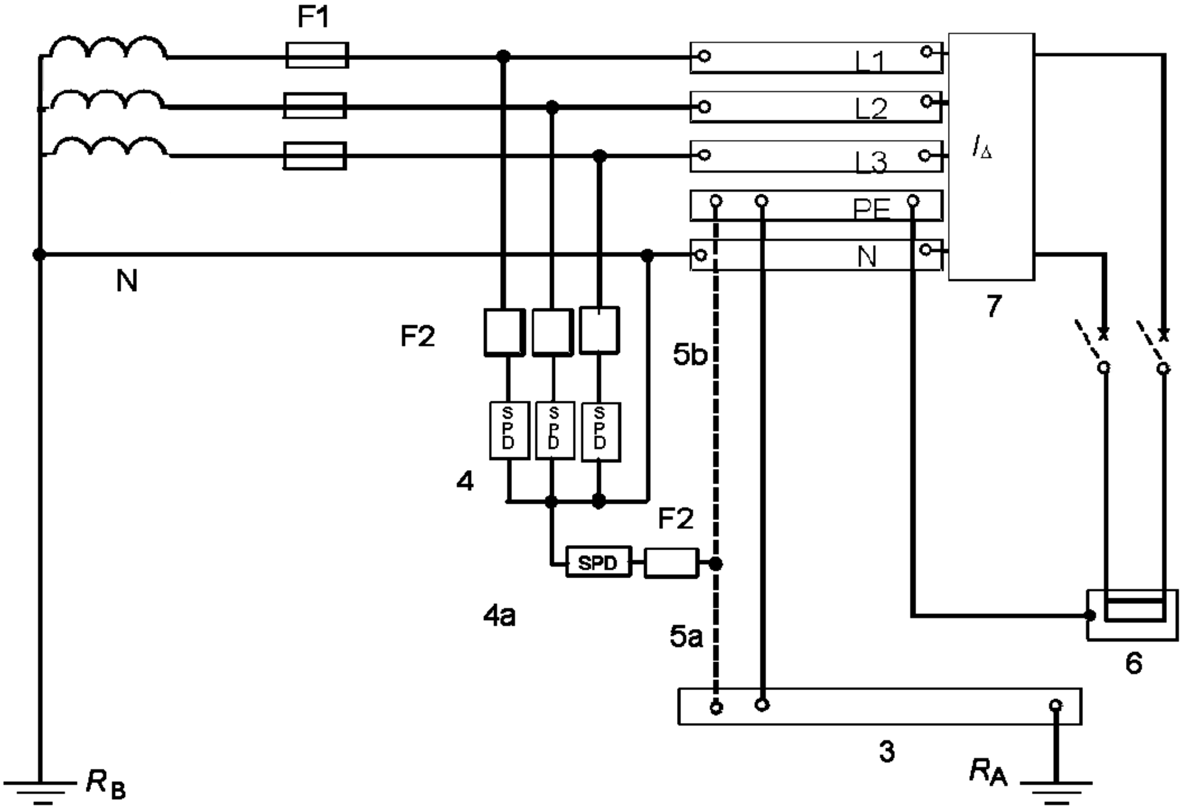
*F*1 — Protective device at the origin of the installation

*F*2 — Protective device required by the manufacturer of the SPD

R_A — Earthing electrode (earthing resistance) of the installation

R_B — Earthing electrode (earthing resistance) of the *supply* system

FIG. 88 SPDs ON THE LOAD SIDE OF A RCD [according to **5.3.4.2.5** (a)]



3 — Main earthing terminal or bar

4 — Surge protective devices
4a Surge protective device
(a combination 4-4a, providing protection against overvoltages of category II)

5 — Earthing connection of surge protective devices, either 5a and/or 5b

6 — Equipment to be protected

7 — Residual current protective device (RCD), placed either upstream or downstream of the busbars

*F*1 — Protective device at the origin of the installation

*F*2 — Protective device required by the manufacturer of the SPD

R_A — Earthing electrode (earthing resistance) of the installation

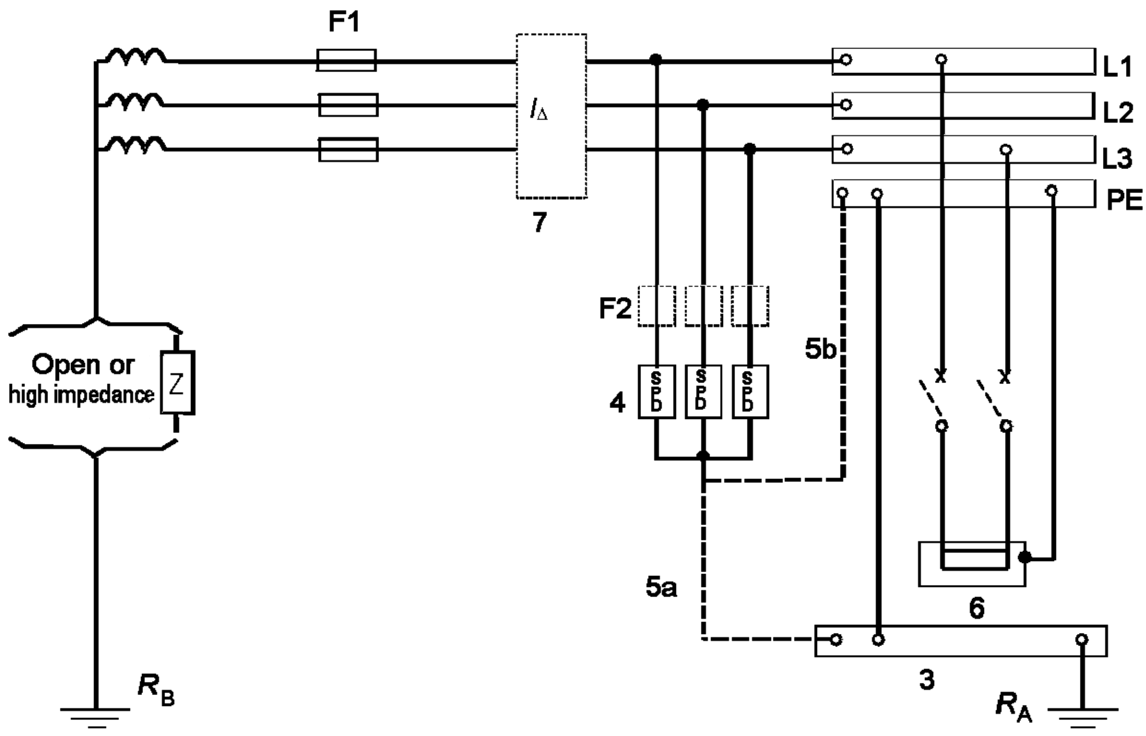
R_B — Earthing electrode (earthing resistance) of the supply system

FIG. 89 SPDS ON THE SUPPLY SIDE OF RCD [according to **5.3.4.2.5** (b)]

ANNEX CC

(*Clause* 5.3)
(*Normative*)

INSTALLATION OF SURGE PROTECTIVE DEVICES IN IT SYSTEMS



3 — Main earthing terminal or bar

4 — Surge protective devices providing protection against overvoltages of category II

5 — Earthing connection of surge protective devices, either 5a and/or 5b

6 — Equipment to be protected

7 — Residual current protective device (RCD)

*F*1 — Protective device at the origin of the installation

*F*2 — Protective device required by the manufacturer of the SPD

R_A — Earthing electrode (earthing resistance) of the installation

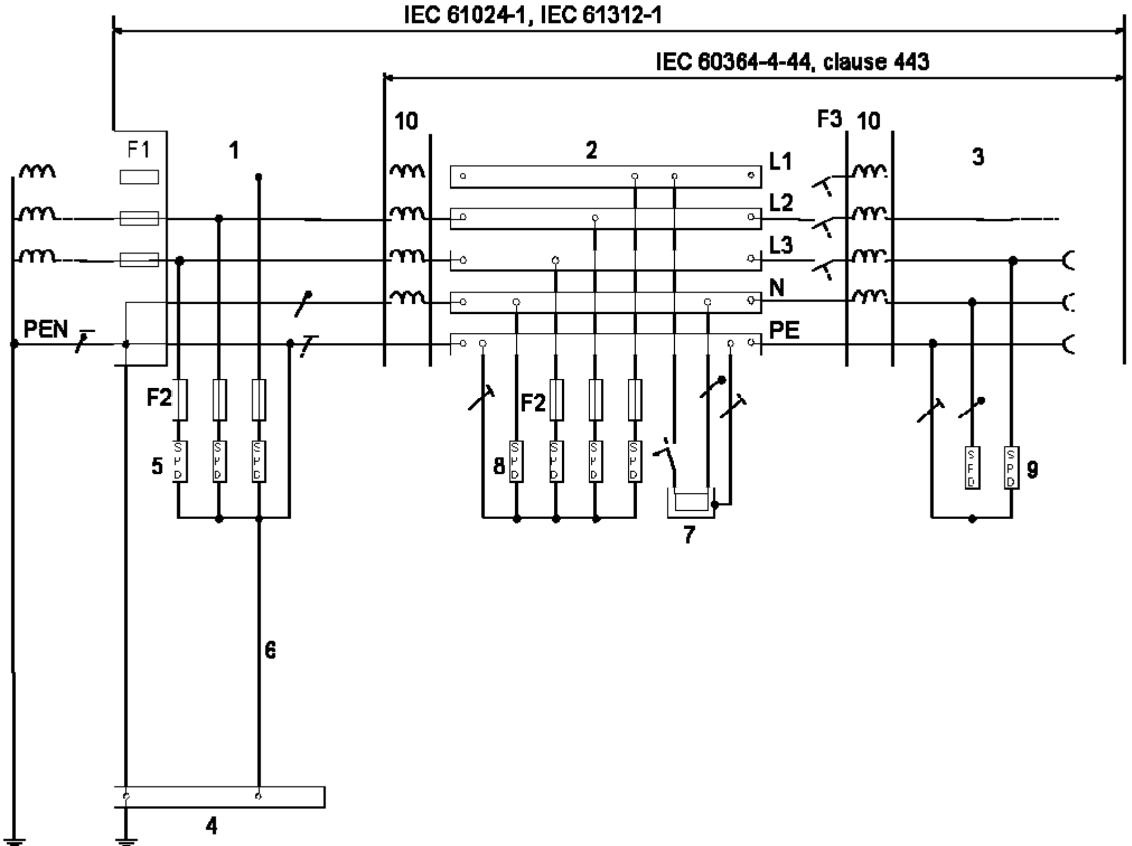
R_B — Earthing electrode (earthing resistance) of the supply system

FIG. 90 SPDS ON THE LOAD SIDE OF A RCD

ANNEX DD

(*Clause* 5.3)
(*Normative*)

INSTALLATION OF CLASS I, II AND III TESTED SPDS, FOR EXAMPLE IN TN-C-S SYSTEMS



1 — Origin of the installation
2 — Distribution board
3 — Distribution outlet
4 — Main earthing terminal or bar
5 — Surge protective device, test class I
6 — Earthing connection (earthing conductor) of surge protective device
7 — Fixed equipment to be protected
8 — Surge protective device, test class II
9 — Surge protective device, test class II or III
10 — Decoupling element or line length
*F*1, *F*2, *F*3 — Overcurrent protective devices

NOTES

1 Reference should be made to IS/ IEC 61643-12 for further information.

2 SPD 5 and 8 can be combined in a single SPD.

FIG. 91 INSTALLATION OF CLASS I, II AND III TESTED SPDS

ANNEX EE

(*Clause* 5.4)

(*Normative*)

METHOD FOR DERIVING THE FACTOR *k* IN 5.4.3.1.2
(*see also* IEC 60724 and IEC 60949)

The factor *k* is determined from the following formula:

$$k = \sqrt{\frac{Q_c(\beta + 20)}{\rho_{20}} \ln\left(\frac{\beta + \theta_f}{\beta + \theta_i}\right)}$$

where

Qc = the volumetric heat capacity of conductor material (J/K mm^3) at 20 °C;

β = the reciprocal of temperature coefficient of resistivity at 0 °C for the conductor (°C);

ρ_{20} = the electrical resistivity of conductor material at 20 °C (Ω.mm);

θ_i = initial temperature of conductor (°C); and

θ_f = final temperature of conductor (°C).

Table 57 Value of Parameters for Different Materials

Material	°C[1]	***Q*c**[1)] J/°C mm^3	**20**[1)] mm	$\sqrt{\frac{Q_c(\beta+20)}{\rho_{20}}}$ $A\sqrt{s}/mm^2$
Copper	234.5	3.45×10^{-3}	17.241×10^{-6}	226
Aluminium	228	2.5×10^{-3}	28.264×10^{-6}	148
Steel	202	3.8×10^{-3}	138×10^{-6}	78

1) Values taken from IEC 60949.

Table 58 Values of *k* for Insulated Protective Conductors not Incorporated in Cables and not Bunched with Other Cables

Conductor insulation	**Temperature °C**[2)]		**Material of Conductor**		
			Copper	Aluminium	Steel
	Initial	Final	Values for *k* [3)]		
70 °C thermoplastic (PVC)	30	160/140 [1)]	143/133 [1)]	95/88[1)]	52/49 [1)]
90 °C thermoplastic (PVC)	30	160/140[1)]	143/133 [1)]	95/88[1)]	52/49 [1)]
90 °C thermosetting (e.g. XLPE and EPR)	30	250	176	116	64
60 °C thermosetting (EPR rubber)	30	200	159	105	58
85 °C thermosetting (EPR rubber)	30	220	166	110	60
185 °C thermosetting (silicone rubber)	30	350	201	133	73

1) The lower value applies to thermoplastic (for example, PVC) insulated conductors of cross-sectional area greater than 300 mm^2.

2) Temperature limits for various types of insulation are given in IEC 60724.

3) For the method of calculating *k*, *see* the formula at the beginning of this Annex.

Table 59 Values of *k* for Bare Protective Conductors in Contact with Cable Covering but not Bunched with Other Cables

Cable covering	Temperature °C 1)		Material of conductor		
			Copper	Aluminium	Steel
	Initial	Final	Values for k 2)		
Thermoplastic(PVC)	30	200	159	105	58
polyethylene	30	150	138	91	50
CSP 3)	30	220	166	110	60

1) Temperature limits for various types of insulation are given in IEC 60724.
2) For the method of calculating *k*, *see* the formula at the beginning of this Annex.
3) CSP = Chloro-Sulphonated Polyethylene.

Table 60 Values of *k* for Protective Conductors as a Core Incorporated in a Cable or Bunched with Other Cables or Insulated Conductors

Conductor Insulation	Temperature °C 2)		Material of Conductor		
			Copper	Aluminium	Steel
	Initial	Final	Values for k 3		
70 °C thermoplastic (PVC)	70	160/140 1)	115/103 1)	76/68 1)	42/37 1)
90 °C thermoplastic (PVC)	90	160/140 1)	100/86 1)	66/57 1)	36/31 1)
90 °C thermosetting (for example, XLPE and EPR)	90	250	143	94	52
60 °C thermosetting (rubber)	60	200	141	93	51
85 °C thermosetting (rubber)	85	220	134	89	48
185 °C thermosetting (silicone rubber)	180	350	132	87	47

1) The lower value applies to thermoplastic (for example, PVC) insulated conductors of cross-sectional area greater than 300 mm^2.
2) Temperature limits for various types of insulation are given in IEC 60724.
3) For the method of calculating *k*, *see* the formula at the beginning of this Annex.

Table 61 Values of *k* for Protective Conductors as a Metallic Layer of a Cable, for example, Armour, Metallic Sheath, Concentric Conductor, etc

Conductor Insulation	Temperature °C 1)		Material of Conductor		
			Copper	Aluminium	Steel
	Initial	Final	Values for k 3)		
70 °C thermoplastic (PVC)	60	200	141	93	51
90 °C thermoplastic (PVC)	80	200	128	85	46
90 °C thermosetting (for example, XLPE and EPR)	80	200	128	85	46
60 °C thermosetting (rubber)	55	200	144	95	52
85 °C thermosetting (rubber)	75	220	140	93	51
Mineral thermoplastic (PVC) covered 2)	70	200	135	–	–
Mineral bare sheath	105	250	135	–	–

1) Temperature limits for various types of insulation are given in IEC 60724.
2) This value shall also be used for bare conductors exposed to touch or in contact with combustible material.
3) For the method of calculating *k*, *see* the formula at the beginning of this Annex.

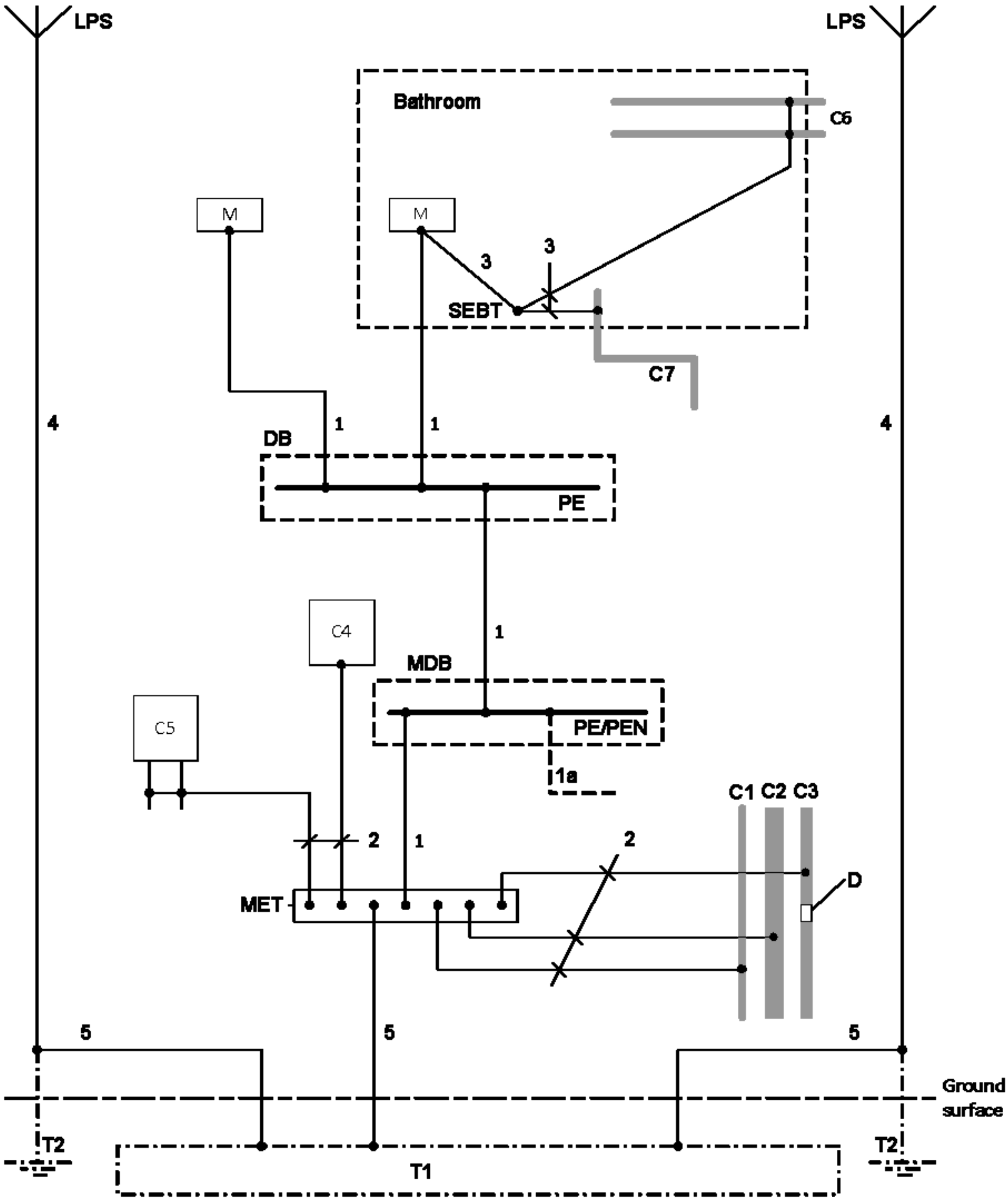
Table 62 Values of *k* for Bare Conductors where There is no Risk of Damage to Any Neighbouring Material by the Temperature Indicated

Conditions	Initial Temperature	Material of Conductor					
		Copper		Aluminium		Steel	
		Maximum Temperature (Final Temperature)	k value	Maximum Temperature (Final Temperature)	k value	Maximum Temperature (Final Temperature)	k value
	°C	°C		°C		°C	
Visible and in restricted area	30	500	228	300	125	500	82
Normal conditions	30	200	159	200	105	200	58
Fire risk	30	150	138	150	91	150	50

ANNEX FF

(*Clause* 5.4)
(*Normative*)

EXAMPLE OF EARTHING ARRANGEMENTS AND PROTECTIVE CONDUCTORS



Key

Symbol	Name	Remark
C	Extraneous-conductive-part	
C1	Water pipe, metal from outside	Or district heating pipe
C2	Waste water pipe, metal from outside	
C3	Gas pipe with insulating insert, metal from outside	
C4	Air-conditioning	
C5	Heating system	
C6	Water pipe, metal e.g. in a bathroom	*See* IEC 60364-7-701 701.4.2.15.2
C7	Waste water pipe, metal e.g. in a bathroom	*See* IEC 60364-7-701 701.4.215.2
D	Insulating insert	
MDB	Main distribution board	
DB	Distribution board	Supplied from the main distribution board
MET	Main earthing terminal	*See* **5.4.2.4**
SEBT	Supplementary equipotential bonding terminal	
T1	Concrete-embedded foundation earth electrode or soil-embedded foundation earth electrode	*See* **5.4.2.2**
T2	Earth electrode for LPS if necessary	*See* **5.4.2.2**
LPS	Lightning protection system (if any)	
PE	PE terminal(s) in the distribution board	
PE/PEN	PE/PEN terminal(s) in the main distribution board	
M	Exposed-conductive-part	
1	Protective earthing conductor (PE)	*See* **5.4.3** Cross-sectional area, *see* **5.4.3.1** Type of protective conductor, *see* **5.4.3.2** Electrical continuity, *see* **5.4.3.3**
1a	Protective conductor, or PEN conductor, if any, from supplying network	
2	Protective bonding conductor for connection to the main earthing terminal	*See* **5.4.4.1**
3	Protective bonding conductor for supplementary bonding	*See* **5.4.4.2**
4	Down conductor of a lightning protection system (LPS) if any	
5	Earthing conductor	*See* **5.4.2.3**

Where a lightning protection system is installed, the additional requirements are given in **6** of IS/IEC 62305-3 : 2006, in particular those given in **6.1** and **6.2**.

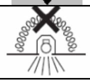
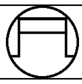
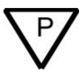
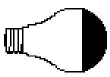
NOTE — Functional earthing conductors are not shown in this Figure.

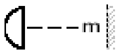
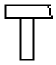
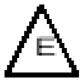
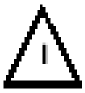
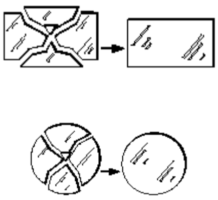
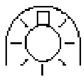
FIG. 92 EXAMPLE OF EARTHING ARRANGEMENTS FOR FOUNDATION EARTH ELECTRODE, PROTECTIVE CONDUCTORS AND PROTECTIVE BONDING CONDUCTORS

ANNEX GG

(*Clause* 5.5)
(*Normative*)

EXPLANATION OF SYMBOLS USED IN LUMINAIRES, IN CONTROLGEAR FOR LUMINAIRES AND IN THE INSTALLATION OF THE LUMINAIRES

	Short-circuit proof (inherently or non-inherently) safety isolating transformer (IS/IEC 61558-2-6 : 2009)
	Luminaire with limited surface temperature (IS 10322 series)
	Luminaire not suitable for covering with thermally insulating material (IS 10322 series)
	Recessed luminaire not suitable for direct mounting on normally flammable surfaces (IS 10322 series)
	Surface mounted luminaire not suitable for direct mounting on normally flammable surfaces (IS 10322 series)
	Luminaire suitable for direct mounting on normally flammable surfaces (IS 10322 series) NOTE — Luminaires suitable for direct mounting on normally flammable surfaces were earlier marked with the symbol  according to IS 10322 series). With the publication of IEC 60598-1 : 2008 (7th edition), luminaires suitable for direct mounting have no special marking and only luminaires not suitable for mounting on normally flammable surfaces are marked with symbols  and/or  (*see* **N-=4** of IS 10322 series for further explanations).
	Independent ballast IEC 60417-5138 (2011-01)
110	Converter with a temperature limitation of 110 °C
	Independent ballast for mounting on normally flammable surfaces (IEC 61347-1 : 2007)
	Luminaires not suitable to direct mounting on flammable surfaces (only suitable to non-flammable surfaces) (IS 10322 series)
	Luminaires suitable for direct mounting in/on normally flammable surfaces when thermally insulating material may cover the luminaire (IS 10322 series)
	Thermally protected ballast/transformer (class P) (IS 10322 series)
	Use of heat-resistant cables for supply, interconnection, or external wiring (number of conductors of cable is optional) (IS 10322 series)
	Luminaires designed for use with bowl mirror lamps (IS 10322 series)
ta . . . °C	Rated maximum ambient temperature (IS 10322 series)

	Warning against the use of cool-beam lamps (IS 10322 series)
	Minimum distance to the lighted objects (m) (IS 10322 series)
	Luminaires suitable for severe conditions of use (IS 10322 series)
	Luminaires for use with high pressure sodium lamp requiring external ignition system (IS 10322 series)
	Luminaires for use with high pressure sodium lamp requiring internal ignition system (IS 10322 series)
	Replace any cracked protective screen (rectangular) or (circular) (IS 10322 series)
	Luminaires designed for use with self-shielded tungsten halogen lamps only (IS 10322 series), and lamps which can be used in open luminaires
	Lamps which can be used only in protected luminaires

ANNEX HH

(*Clause* 5.6)
(*Normative*)

GUIDANCE FOR EMERGENCY LIGHTING

The values in ISO 30061 should be considered but additional details of suitable systems are given in Table 63. Annex HH serves as an informative guide for countries that do not have specific rules or their own guidelines.

Table 63 Guidance for Emergency Lighting
(*Clause* 5.6.7.3)

Examples of Applications	**Requirements**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Extended Duration or Remote Controlled Circuit	Escape Sign Luminaires in Maintained Mode	Central Power Supply System	Low Power Supply System	Self-Contained Battery Unit	Motor-Generator Unit with no Break (0 s)	Motor-Generator Unit with Short Break (< 0.5 s)	Motor-Generator Unit with Medium Break (< 15 s)	Dual Supply System
Assembly halls, assembly rooms	**	†	†	†	†	†	†	†	†
Exhibition halls	**	†	†	†	†	†	†	†	†
Theatres, cinemas	**	†	†	†	†	†	†	†	†
Sports arenas	**	†	†	†	†	†	†	†	†
Sales areas	**	†	†	†	†	†	†	†	†
Restaurants	**	†	†	†	†	†	†	†	†
Hospitals, treatment centres	**	†	†	†	†	†	†	†	†
Hotels, guest houses *	**	†	†	†	†	†	†	†	†
Residential care homes *	**	†	†	†	†	†	†	†	†
High-rise buildings *	**	†	†	†	†	†	†	†	†
Schools	**	†	†	†	†	†	†	†	†
Enclosed car parks		†	†	†	†	†	†	†	†
Escape routes in workplaces		†	†	†	†	†	†	†	†
High risk task areas		†	†	†	†	†	†	†	†
Stages	**	†	†	†	†	†	†	†	†

† denotes suitable systems.
* In premises (guest houses, hotels, residential care homes and high-rise buildings) used the whole day, the rated operating time for the emergency lighting should be 8 h or shall be switchable with illuminated push buttons for a fixed time by the occupants. In this case, the push buttons and their timing equipment should also run in the emergency mode.
** Denotes applications which require either extended duration or a circuit like the remote controlled circuit to ensure protection for longer than 60 min.

ANNEX JJ

(*Clause* 5.6)
(*Normative*)

GUIDANCE FOR FIRE PROTECTION EQUIPMENT

Table 64 Guidance for Safety Equipment

(*Clause* 5.6.8.4)

Examples for safety equipment	Requirements									
	1	2	3	4	5	6	7	8	9	10
	Rated operating time of the source, h	Response time of the source, s, Max.	Central power supply system	Low power supply system	Self-contained battery unit	Motor-generator unit with no break (0 s)	Motor-generator unit with short break (< 0.5 s)	Motor-generator unit with medium break (< 15 s)	Dual supply system	Monitoring and changeover in the case of failure of the source
Installations for fire pumps	12	15				†	†	†	†	†
Fire rescue service lifts	8	15				†	†	†	†	†
Lifts with special requirements	3	15				†	†	†	†	†
Devices of alarm and issue of instructions	3	15	†	†		†	†	†	†	†[1)]
Smoke and heat extraction equipment	3	15	†	†	†	†	†	†	†	†[1)]
CO warning equipment	1	15	†	†	†	†	†	†	†	†[1)]

[1)] Only in case of no separate safety supply equipment.

† Denotes suitable systems.

ANNEX KK

(*Clause* 6.2.3.5)
(*Normative*)

METHODS FOR MEASURING THE INSULATION RESISTANCE/ IMPEDANCE OF FLOORS AND WALLS TO EARTH OR TO THE PROTECTIVE CONDUCTOR

KK-1 GENERAL

Measurement of impedance or resistance of insulating floors and walls shall be carried out with the system voltage to earth and nominal frequency, or with a lower voltage of the same nominal frequency combined with a measurement of insulation resistance. This may be done, for example, in accordance with the following methods of measurement:

1) a.c. systems
   – by measurement with the nominal a.c. voltage, or
   – by measurement with lower a.c. voltages (minimum 25 V) and additionally by an insulation test using a minimum test voltage 500 V (d.c.) for nominal system voltages not exceeding 500 V and a minimum test voltage 1 000 V (d.c.) for nominal system voltages above 500 V.

The following voltage sources may be used optionally:

a) the earthed system voltage (voltage to earth) that exists at the measuring point;
b) the secondary voltage of a double wound transformer; and
c) an independent voltage source at the nominal frequency of the system.

In cases as specified under (b) and (c), the measuring voltage shall be earthed for the measurement.

For safety reasons, when measuring voltages above 50 V, the maximum output current shall be limited to 3.5 mA.

2) d.c. systems
   – insulation test by using a minimum test voltage of 500 V (d.c.) for nominal system voltages not exceeding 500 V;
   – insulation test by using a minimum test voltage of 1000 V (d.c.) for nominal system voltages above 500 V.

The insulation test should be made using measuring equipment in accordance with IS/IEC 61557-2.

KK-2 TEST METHOD FOR MEASURING THE IMPEDANCE OF FLOORS AND WALLS WITH a.c. VOLTAGE

Current I is fed through an ammeter to the test-electrode from the output of the voltage source or from the phase conductor L. The voltage U_X at the electrode is measured by means of a voltmeter with internal resistance of at least 1 MΩ towards PE.

The impedance of the floor insulation will then be: $Z_X = U_X / I$.

The measurement for ascertaining the impedance shall be carried out at as many points as deemed necessary, selected at random, with a minimum of three.

The test electrodes may be either of the following types. In case of dispute, the use of test electrode 1 is the reference method.

KK-3 TEST ELECTRODE 1

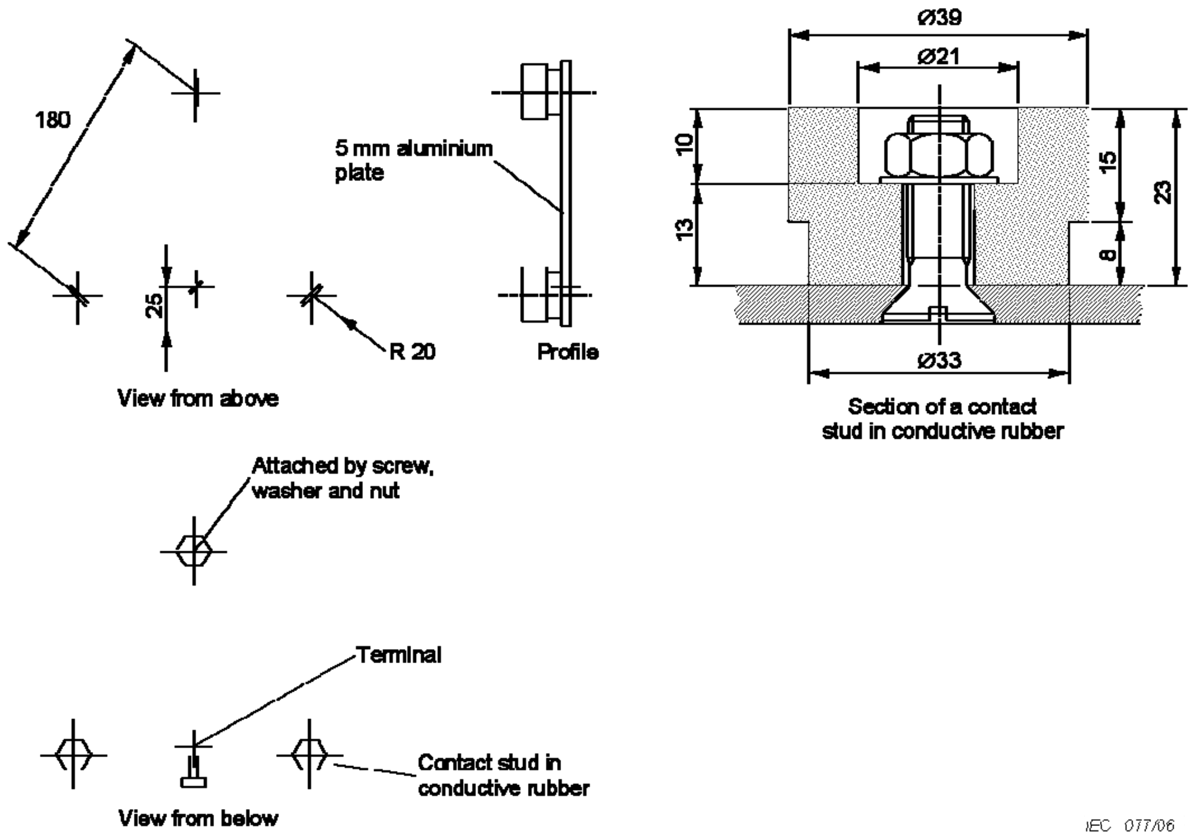
The electrode comprises a metallic tripod of which the parts resting on the floor form the points of an equilateral triangle. Each supporting point is provided with a flexible base ensuring, when loaded, close contact with the surface being tested over an area of approximately 900 mm^2 and presenting a resistance of less than 5 000 Ω.

Before measurements are made, the surface being tested is cleaned with a cleaning fluid. While measurements are being made, a force of approximately 750 N for floors or 250 N for walls is applied to the tripod.

KK-4 TEST ELECTRODE 2

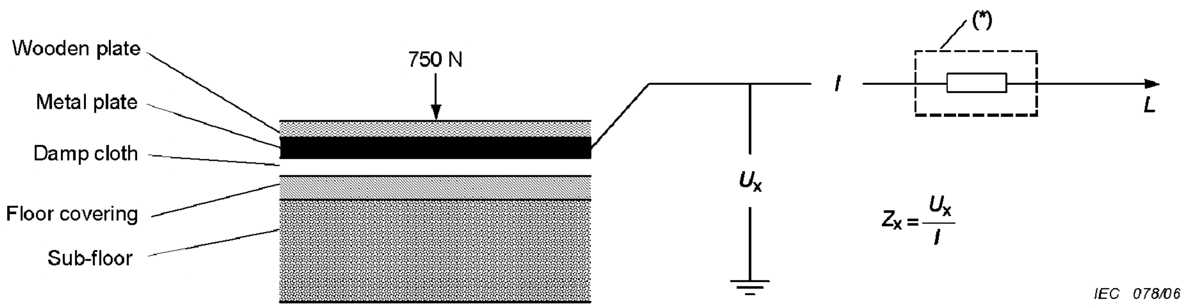
The electrode comprises a square metallic plate with sides that measure 250 mm, and a square of damped, water-absorbent paper, or cloth, from which surplus water has been removed, with sides that measure approximately 270 mm. The paper is placed between the metal plate and the surface being tested.

During measurement a force of approximately 750 N for floors or 250 N for walls is applied on the plate.



All dimensions in millimetres.

FIG. 93 TEST ELECTRODE 1



(*) Protection against unintentional contact by a resistance limiting the current to 3.5 mA.

FIG. 94 TEST ELECTRODE 2

ANNEX LL

(*Clause* 6.2.3.6.2)
(*Normative*)

METHOD LL1, LL2 AND LL3

LL-1 METHOD LL1 — MEASUREMENT OF EARTH ELECTRODE RESISTANCE

As an example, the following procedure may be adopted when the measurement of the earth resistance is to be made (*see* Fig. 95).

An alternating current of a steady value is passed between the earth electrode, T, and an auxiliary earth electrode, T_1, placed at a distance from T such that the resistance areas of the two electrodes do not overlap.

A second auxiliary earth electrode, T_2, which may be a metal spike driven into the ground, is then inserted half-way between T and T_1, and the voltage drop between T and T_2 is measured.

The resistance of the earth electrode is then the voltage between T and T_2, divided by the current flowing between T and T_1, provided that there is no overlap of the resistance areas.

To check that the resistance of the earth electrode is a true value, two further readings are taken with the second auxiliary electrode T_2 moved 6 m from and 6 m nearer to T, respectively. If the three results are substantially in agreement, the mean of the three readings is taken as the resistance of the earth electrode T. If there is no such agreement, the tests are repeated with the distance between T and T_1 increased.

LL-2 METHOD LL2 — MEASUREMENT OF THE FAULT LOOP IMPEDANCE

Measurement of the fault loop impedance shall be made in accordance with the requirements of **6.2.3.6.3**.

As an example, the following method by means of voltage drop may be used.

NOTES

1 The method proposed in this Annex gives only approximate values of the fault loop impedance as it does not take into account the vectorial nature of the voltage, that is, of the conditions existing at the time of an actual earth fault. The degree of approximation is, however, acceptable provided that the reactance of the circuit concerned is negligible.

2 It is recommended that a continuity test be made between the main earthing terminal and the exposed- conductive-parts before carrying out the fault loop impedance test.

3 Attention is drawn to the fact that the present method presents difficulties in the application.

The voltage of the circuit to be verified is measured (*see* Fig. 96) with and without connection of a variable load resistance, and the fault loop impedance is calculated from the following formula:

$$Z = \frac{U_1 - U_2}{I_R}$$

where

Z = the fault loop impedance;

U_1 = the voltage measured without connection of the load resistance;

U_2 = the voltage measured with connection of the load resistance; and

I_R = the current through the load resistance.

NOTE — The difference between U_1 and U_2 should be significant.

LL-3 METHOD LL3 — MEASUREMENT OF EARTH LOOP RESISTANCE WITH CURRENT CLAMPS

This measuring method works with existing earth-loops within a meshed grounding system, as shown in Fig. 97.

The first clamp inducts a measuring voltage U to the loop, the second clamp measures the current I within the loop. The loop resistance can be calculated by dividing the voltage U by the current I.

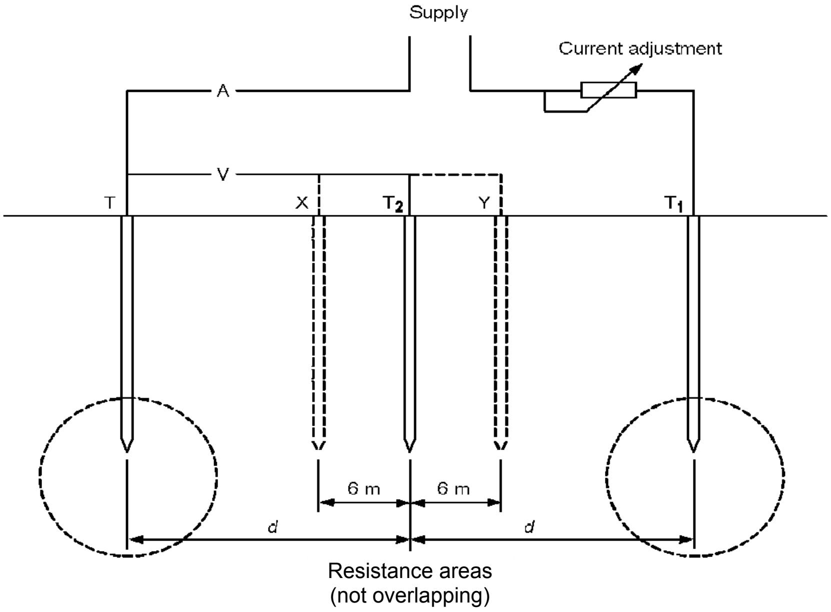
As the resulting value of parallel resistances R_1 ... R_n is normally negligible, the unknown resistance is equal to the measured loop resistance or a little lower.

Each clamp can be single connected to an instrument or can be combined into one special clamp.

This method is directly applicable to TN systems and within meshed earthing system of TT systems.

In TT systems, where only the unknown earth connection is available, the loop can be closed by a short-time connection between earth electrode and neutral conductor (quasi TN system) during measurement.

To avoid possible risks due to currents caused by potential differences between neutral and earth, the system should be switched off during connection and disconnection.



Key

T — earth electrode under test, disconnected from all other sources of supply;
T_1— auxiliary earth electrode;
T_2— second auxiliary earth electrode;
X — alternative position of T_2 for check measurement; and
Y — further alternative position of T_2 for the other check measurement.

FIG. 95 MEASUREMENT OF EARTH ELECTRODE RESISTANCE

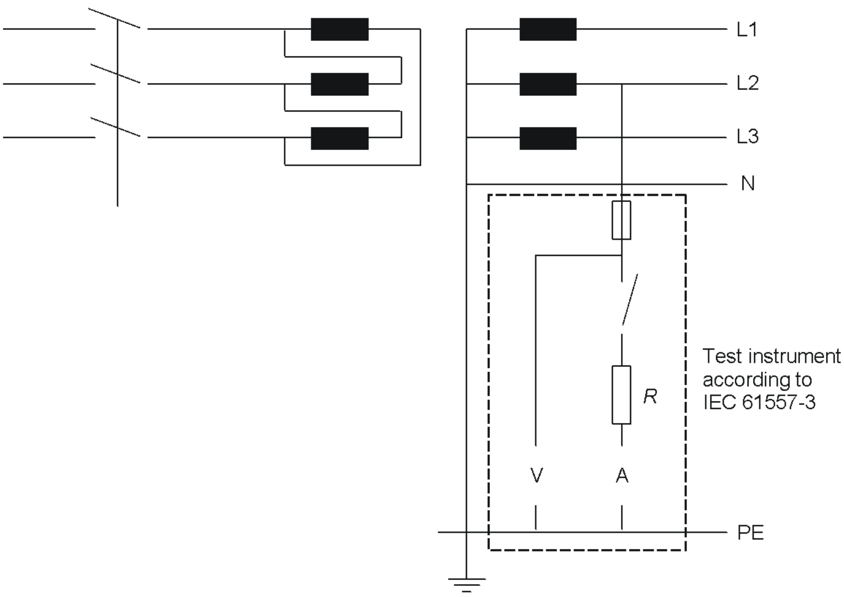
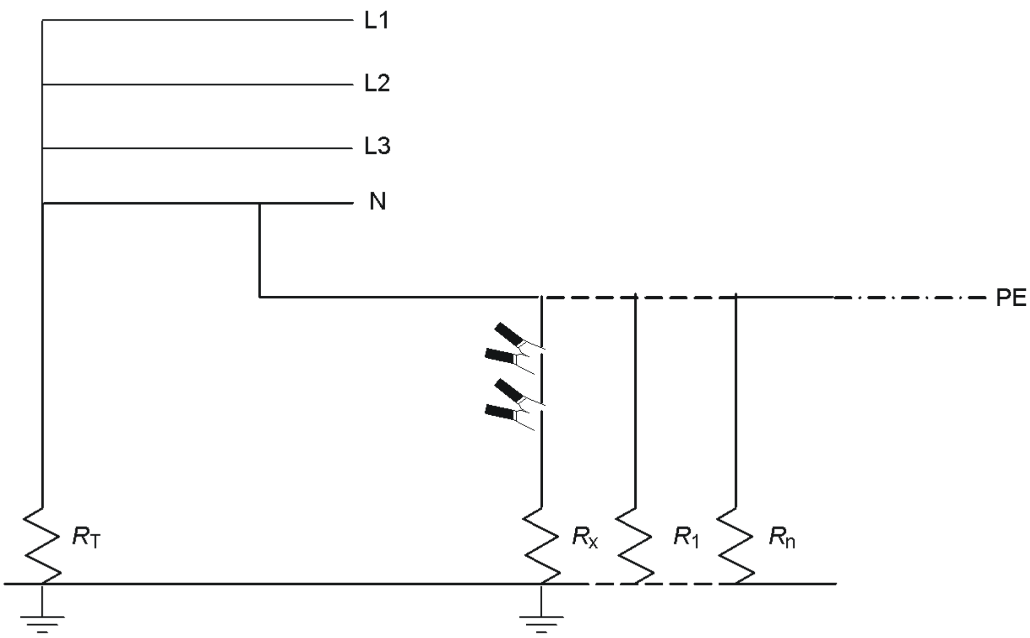


FIG. 96 MEASUREMENT OF FAULT LOOP IMPEDANCE BY VOLTAGE DROP



R_T — earth-connection of transformer

R_x — unknown earth-resistance to be measured

$R_1 ... R_n$ — parallel earth-connections connected by an equipotential bonding or a PEN conductor

FIG. 97 MEASUREMENT OF EARTH LOOP RESISTANCE WITH CURRENT CLAMPS

ANNEX MM

(*Clause* 6.2)

(*Normative*)

GUIDANCE ON THE APPLICATION OF THE RULES OF CLAUSE 6.2 INITIAL VERIFICATION

The numbering of the clauses and subclauses of this Annex follows the numbering of **6.2**.

The absence of reference of clauses or subclauses means that no additional explanation is given to them.

MM-6.2.2 *Inspection*

MM-6.2.2.2 This inspection is also intended to check that the installation of the equipment is in accordance with the manufacturer's instructions in order that its performance is not adversely affected.

MM-6.2.2.3

b) presence of fire barriers and other precautions against propagation of fire and protection against thermal effects (**4.3** and **5.2.10**)

– presence of fire barriers (**5.2.10.2**)

The installation of the seals is verified to confirm compliance with the erection instructions associated with IEC type test for the relevant product (under consideration by ISO).

No other test is required after this verification.

– protection against thermal effects (**4.3**)

The rules of **4.3** concerning the protection against thermal effects apply for normal service, that is, in the absence of a fault.

The overcurrent protection of wiring systems is the object of **4.4** and of **5.3.4**.

The operation of a protective device resulting from a fault, including short circuits, or from overloads, is considered as normal service.

– protection against fire (**4.3.2**)

The requirements of **4.3.2** for locations with fire hazards assume that protection against overcurrent is in compliance with the rules of **4.4**.

c) and d) Selection of conductors for current-carrying capacity and voltage drop and choice and setting of protective and monitoring devices.

The selection of the conductors including their materials, installation and cross-sectional area, their erection and the setting of the protective devices is verified according to the calculation of the designer of the installation in compliance with the rules of this standard, particularly **4.2**, **4.4**, **5.2**, **5.3** and **5.4**.

i) Presence of diagrams, warning notices or other similar information

A diagram, as specified by **5.1.4.5**, is particularly necessary when the installation comprises several distribution boards.

m) Adequacy of connections of conductors

The purpose of this verification is to check whether the clamping means are adequate for the conductors to be connected and whether the connection is properly made.

In case of doubt, it is recommended to measure the resistance of the connections. This resistance should not exceed the resistance of a conductor having a length of 1 m and a cross-sectional area equal to the smallest cross-sectional area of the conductors connected.

p) Accessibility of equipment for convenience of operation, identification and maintenance

It shall be verified that the operating devices are so arranged that they are easily accessible to the operator.

For devices for emergency switching, *see* **5.3.7.4.2**.

For devices for switching off for mechanical maintenance, *see* **5.3.7.5.4.2**.

MM-6.2.3 *Testing*

MM-6.2.3.2 *Continuity of protective conductors*

This testing is required for the verification of the protection conditions by means of automatic disconnection of supply (*see* **6.2.3.6**) and is considered as satisfactory if the device used for the test gives an appropriate indication.

NOTE — The current used for testing should be sufficiently low as not to cause a risk of fire or explosion.

MM-6.2.3.3 *Insulation resistance of the electrical installation*

The measurements shall be carried out with the installation isolated from the supply. Generally, the insulation measurement is carried out at the origin of the installation.

If the value measured is less than that specified in Table 15, the installation may be divided into several circuit groups and the insulation resistance of each group shall be measured. If, for one group of circuits, the measured value is less than that specified in Table 15, the insulation resistance of each circuit of this group shall be measured.

When some circuits or parts of circuits are disconnected by undervoltage devices (for instance contactors) interrupting all live conductors, the insulation resistance of these circuits or parts of circuits is measured separately.

MM-6.2.3.4 *Protection by SELV, PELV or by electrical separation*

MM-6.2.3.4.3 *Protection by separation of circuits*

Where equipment includes both a separated circuit and other circuits, the required insulation is obtained by constructing the equipment in accordance with the safety requirements of the relevant standards.

MM-6.2.3.6 *Protection by automatic disconnection of the supply*

MM-6.2.3.6.1 *General*

According to **4.2**, when verifying the compliance with the maximum disconnecting times, the test should be applied at a residual current equal to 5 $I\Delta_n$.

MM-6.2.3.6.2 *Measurement of fault loop impedance: consideration of the increase of the resistance of the conductors with the increase of temperature*

As the measurements are made at room temperature, with low currents, the procedure hereinafter described may be followed to take into account the increase of resistance of the conductors with the increase of temperature due to faults, to verify, for TN systems, the compliance of the measured value of the fault loop impedance with the requirements of **4.2.11.4**.

The requirements of **4.2.11.4** are considered to be met when the measured value of the fault loop impedance satisfies the following equation:

$$Z_s(m) \leq \frac{2}{3} \times \frac{U_0}{I_a}$$

where

$Z_S(m)$ = the measured impedance of the fault current loop starting and ending at the point of fault (Ω);

U_o = the line conductor to earthed neutral voltage (V); and

I_a = the current causing the automatic operation of the protective device within the time stated in Table 1 or within 5 s according to the conditions stated in **4.2.11.4**.

Where the measured value of the fault loop impedance exceeds $2U_o/3I_a$, a more precise assessment of compliance with **4.2.11.4** may be made, evaluating the value of the fault loop impedance according to the following procedure:

a) the supply line conductor-earthed neutral loop impedance, Z_e, is first measured at the origin of the installation;

b) the resistance of the line conductor and protective conductor of the distribution circuit(s) are then measured;

c) the resistance of the line conductor and protective conductor of the final circuit are then measured;

d) the values of the resistance measured in accordance with (a), (b) and (c) are increased on the basis of the increase of the temperature, taking into consideration, in the case of fault currents, the energy let-through of the protective device;

e) the values of the resistance increased in accordance with (d) are finally added to the value of the supply line conductor-earthed neutral loop impedance, Z_e, so obtaining a realistic value of Z_S under fault conditions.

ANNEX NN

(*Clause* 6.2.3.10)
(*Normative*)

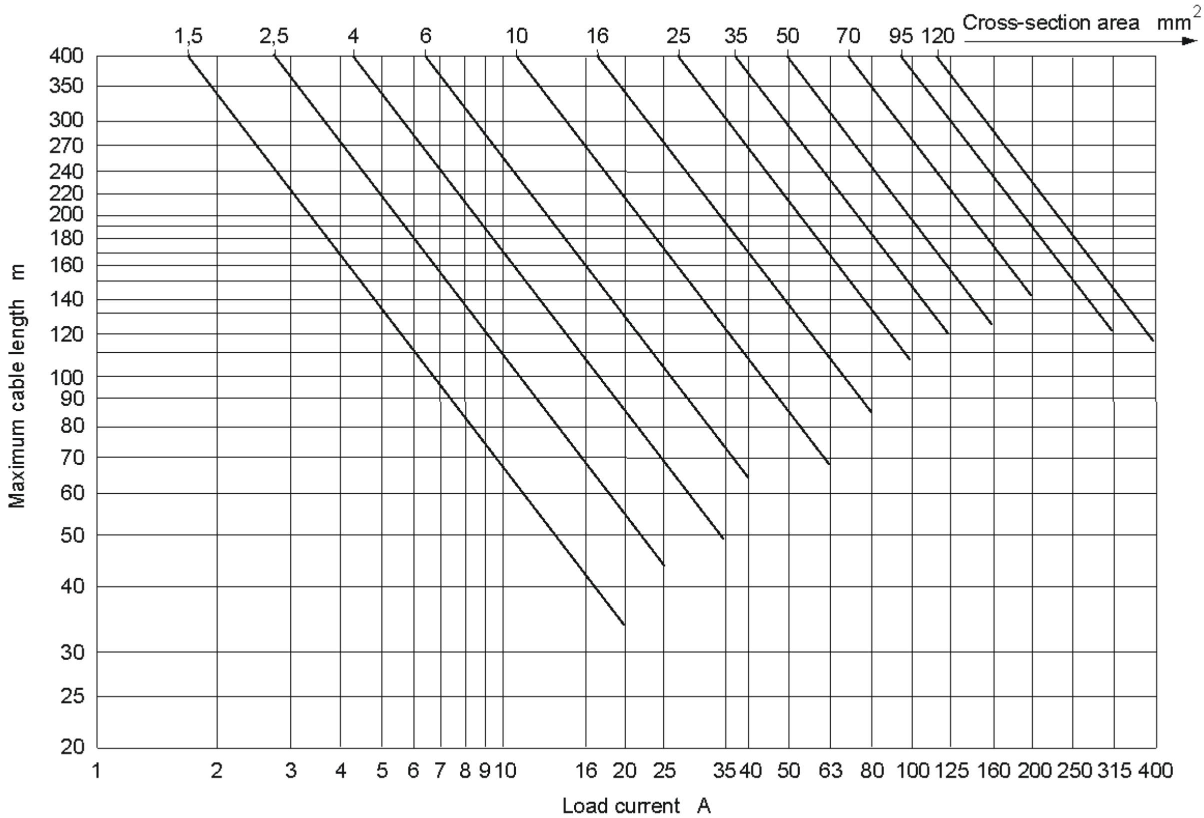
EXAMPLE OF A DIAGRAM SUITABLE FOR THE EVALUATION OF THE VOLTAGE DROP

Maximum cable length for 4 percent voltage drop at 400 V a.c. nominal voltage and 55 °C wiring temperature.

Three-phase wiring system, PVC insulated cables, copper wiring

For single-phase wiring system (230 V a.c.): divide maximum cable length by 2

For aluminium wiring: divide maximum cable length by 1.6



NOTE — The diagram above is not intended to give guidance on the current-carrying capacity of the conductors.

FIG. 98 EXAMPLE OF A DIAGRAM SUITABLE FOR THE EVALUATION OF THE VOLTAGE DROP

ANNEX PP

(*Clause* 6)

(*Normative*)

RECOMMENDATION FOR ELECTRICAL EQUIPMENT, WHICH IS BEING RE-USED IN ELECTRICAL INSTALLATIONS

Re-used equipment is equipment that has been previously installed.

For re-used equipment, documents should be available, at the time of the verification, containing at least the following information:

a) type of re-used equipment;

b) manufacturer;

c) relevant installation details;

d) test instruments;

e) results of inspection; and

f) tests performed, including verification of disconnecting times for RCDs, and test results.

ANNEX QQ

(*Clause* 6)

(Normative)

DESCRIPTION OF THE INSTALLATION FOR VERIFICATION

NOTE — Particularly suitable for domestic installations.

Type of verification:

❑ Initial verification

❑ Periodic verification

Client name and address:

Installation address:

Installer name and address:

Installation:

❑ New ❑ Modification

❑ Extension ❑ Existing

Name of inspector:

Description of installation work:

Date of inspection: Signature: ………………………………………..

Identification of instruments used:

	Type	Model	Serial number

Supply characteristics and earthing arrangements			Tick boxes and enter details, as appropriate
Earthing arrangements	Number and type of live conductors	Nature of supply parameters	Incoming supply protective device characteristics
Supply authority ❑ Consumer's earth electrode ❑			
System types TN-C ❑ TN-C-S ❑ TN-S ❑ TT ❑ IT ❑	a.c ❑ d.c. ❑ 1-phase, 2-wire (LN) ❑ 2-pole ❑ 1-phase, 3-wire (LLM) ❑ 3-pole ❑ 2-phase, 3-wire (LLN) ❑ other ❑ 3-phase, 3-wire (LLL) ❑ other ❑ 3-phase, 4-wire (LLLN) ❑ other ❑	Nominal voltage, U/U_0 (1)........................V Nominal frequency, f (1)......................Hz Prospective highest short-circuit current, I_{cc} (2)…………… ……..............kA External earth fault loop impedance, Z_e (2)................................Ω NOTES 1) By enquiry 2) By enquiry, or by measurement or by calculation	Type:................... Nominal current rating:...............A RCD sensitivity, where applicable ....mA
Alternative source ❑ of supply (to be detailed on attached schedules)			

Details of consumers earth electrode (where applicable)			
Type	Material		
	Cu	Fe	Other
Foundation earth electrode	❑	❑	❑
Ground earth electrode	❑	❑	❑
Rod	❑	❑	❑
Tape	❑	❑	❑
Other:	❑	❑	❑
Location:			
Resistance to earth:..Ω			
NOTE — In existing installations where the above information cannot be ascertained, this fact should be noted.			

Earthing and main bonding conductors			
Earthing conductor:	material......................	csa1)................... mm^2	connection verified ❑
Main equipotential bonding conductors:	material......................	csa...................... mm^2	connection verified ❑
To incoming water and/or gas service ❑		To other elements:..	
Supplementary equipotential bonding			
Bathrooms/showers:	material......................	csa.................. mm^2	connection verified ❑
Swimming pools:	material......................	csa.................. mm^2	connection verified ❑
Other: (please state)	material......................	csa................. mm^2	connection verified ❑
1) csa: conductor cross-sectional area.			

Isolation and protective devices at the origin of installation				
	Type	No. of poles	Ratings	
Main switch			 	V A
Fuse or circuit breaker			I_n I_{cn}, I_{cu}, I_{cs}	A kA
RCD			I_n $I_{\Delta n}$	A mA

ANNEX RR
(*Clause* 6)
(*Normative*)

FORM FOR INSPECTION OF ELECTRICAL INSTALLATIONS
(*see* EXAMPLES IN CLAUSE RR -2)

RR-1 FORM FOR INSPECTION OF ELECTRICAL INSTALLATIONS

NOTE — Particularly suitable for domestic installations.

A Protection Against Direct Contact

	Item	Compliance (NOTE 1)	Comments
i)	Insulation of live parts		
ii)	Barriers		
iii)	Enclosures		

B Equipment

	Equipment	Selection (NOTE 2)	Erection (NOTE 1)	Comments
i)	Cables			
ii)	Wiring accessories			
iii)	Conduits			
iv)	Trunking			
v)	Distribution equipment			
vi)	Luminaires			
vii)	Heating			
viii)	Protective devices RCD, CBs, etc.			
ix)	Other			

C Identification

	Item	Presence	Correct location	Correct wording	Comments
i)	Labelling of protective devices, switches and terminals				
ii)	Warning notices				
iii)	Danger notices				
iv)	Identification of conductors				
v)	Isolation devices				
vi)	Switching devices				
vii)	Diagrams and schedules				

NOTES

1 Enter C if it complies with (national) installation standard, NC if it does not comply.

2 Visible indication of compliance with the appropriate product standard. In case of doubt, a declaration of conformity with the standard needs to be obtained from the manufacturer (for example, from the catalogues).

RR-2 EXAMPLES OF ITEMS TO BE CHECKED WHEN CARRYING OUT AN INSTALLATION INSPECTION

General

- ❑ Good workmanship and proper materials have been used
- ❑ Circuits to be separate (no interconnection of neutrals between circuits)
- ❑ Circuits to be identified (neutral and protective conductors in same sequence as line conductors)
- ❑ Disconnection times likely to be met by installed protective devices
- ❑ Adequate number of circuits
- ❑ Adequate number of socket-outlets provided
- ❑ All circuits suitably identified
- ❑ Suitable main switch provided
- ❑ Main isolators to break all live conductors, where applicable
- ❑ Main earthing terminal provided, readily accessible and identified
- ❑ Conductors correctly identified
- ❑ Correct fuses or circuit breakers installed
- ❑ All connections secure
- ❑ The whole installation has been earthed in accordance with national standards
- ❑ Main equipotential bonding connects services and other extraneous-conductive-parts to the main earth facility
- ❑ Supplementary bonding has been provided in all bath and shower rooms
- ❑ All live parts are either insulated or contained within enclosures

A Protection Against Direct Contact

- ❑ Insulation of live parts
- ❑ Barriers (check for adequacy and security)
- ❑ Enclosures have suitable degree of protection appropriate to external influences
- ❑ Enclosures have cable entries correctly sealed
- ❑ Enclosures have unused entries blanked off where necessary

B Equipment

1. Cables and Cords

Non-flexible cables and cords

- ❑ Correct type
- ❑ Correct current rating
- ❑ Non-sheathed cables protected by enclosure in conduit, duct or trunking
- ❑ Sheathed cables routed in allowed zones or additional mechanical protection provided
- ❑ Where exposed to direct sunlight, of a suitable type
- ❑ Correctly selected and installed for use. for example. buried
- ❑ Correctly selected and installed for use on exterior walls
- ❑ Internal radii of bends in accordance with relevant standard
- ❑ Correctly supported
- ❑ Joints and connections electrically and mechanically sound and adequately insulated
- ❑ All wires securely contained in terminals etc, without strain
- ❑ Enclosure of terminals
- ❑ Installation to permit easy replacement in case of damaged conductors
- ❑ Installation of cables to avoid excessive strain on conductors and terminations
- ❑ Protection against thermal effects

- ❑ One conduit allowed for conductors of the same circuit (derogation *see* **5.2**)
- ❑ Connection of conductors (size of terminals adapted to cross-sectional area of conductors); sufficient pressure contact shall be guaranteed
- ❑ Selection of conductors for current-carrying capacity and voltage drop considering the method of laying
- ❑ Identification of N, PEN and PE conductors

Flexible cables and cords

- ❑ Selected for resistance to damage by heat
- ❑ Prohibited core colours not used
- ❑ Joints to be made using cable couplers
- ❑ Final connections to other current-using equipment properly secured or arranged to prevent strain on connections
- ❑ Mass supported by pendants not exceeding correct values

Protective conductors

- ❑ Protective conductors provided to every point and accessory
- ❑ Flexible conduit to be supplemented by a protective conductor
- ❑ Minimum cross-sectional area of copper conductors
- ❑ Insulation, sleeving and terminations identified by colour combination green-and-yellow
- ❑ Joints sound
- ❑ Main and supplementary bonding conductors of correct size

2. Wiring Accessories (Luminaires – see below)
General (applicable to each type of accessory)

- ❑ Visible indication of compliance with the appropriate product standard, where required in the relevant product standard
- ❑ Box or other enclosure securely fixed
- ❑ Edge of flush boxes not projecting beyond wall surface
- ❑ No sharp edges on cable entries, screw heads, etc. which could cause damage to cables
- ❑ Non-sheathed cables, and cores of cable from which the sheath has been removed, not exposed outside the enclosure
- ❑ Correct connection
- ❑ Conductors correctly identified
- ❑ Bare protective conductors sleeved green/yellow
- ❑ Terminals tight and containing all strands of the conductors
- ❑ Cord grip correctly used or clips fitted to cables to prevent strain on the terminals
- ❑ Adequate current rating
- ❑ Suitable for the conditions likely to be encountered

Socket-outlets

- ❑ Mounting height above the floor or working surface suitable
- ❑ Correct polarity
- ❑ Circuit protective conductor connected directly to the earthing terminal of the socket outlet

Joint boxes

- ❑ Joints accessible for inspection
- ❑ Joints protected against mechanical damage

Connection unit

- ❑ Out of reach of a person using a bath or shower
- ❑ Correct rating of fuse fitted

Cooker control unit

- ❑ Sited to the side and low enough for accessibility and to prevent flexes trailing across radiant plates
- ❑ Cable to cooker fixed to prevent strain on connections

Lighting controls

- ❑ Single pole switches connected in line conductors only
- ❑ Correct colour coding or marking of conductors
- ❑ Earthing of exposed metalwork, for example, metal switch plate
- ❑ Switch out of reach of a person using a bath or shower

Fixed connection of current-using equipment (including luminaires)

- ❑ Installation according to manufacturer recommendations
- ❑ Protection against direct contact

3. Conduits
General

- ❑ Visible indication of compliance with the appropriate product standard, where required in the relevant product standard
- ❑ Securely fixed, covers in place and adequately protected against mechanical damage
- ❑ Number of cables for easy draw-in not exceeded
- ❑ Adequate boxes for drawing in cables
- ❑ Radius of bends such that cables are not damaged
- ❑ Suitable degree of protection appropriate to external influences

Rigid metal conduit

- ❑ Connected to the main earthing terminal
- ❑ Line and neutral cables enclosed in the same conduit
- ❑ Conduit suitable for damp and corrosive situations

Flexible metal conduit

- ❑ Separate protective conductor provided
- ❑ Adequately supported and terminated

Rigid non-metallic conduit

- ❑ Provision for expansion and contraction
- ❑ Boxes and fixings suitable for mass of luminaire suspended at expected temperature
- ❑ Protective conductor provided

4. Trunking

General

- ❑ Visible indication of compliance with the appropriate product standard, where required in the relevant product standard
- ❑ Securely fixed and adequately protected against mechanical damage
- ❑ Selected, erected and routed so that no damage is caused by the ingress of water
- ❑ Cables supported for vertical runs
- ❑ Suitable degree of protection appropriate to external influences and locations

Metal trunking — Additional requirements

- ❑ Phase and neutral cables enclosed in the same metal trunking
- ❑ Protected against damp or corrosion
- ❑ Correctly earthed
- ❑ Joints mechanically sound, and of adequate continuity with links fitted

5. Distribution Equipment

- ❑ Visible indication of compliance with the appropriate product standard, where required in the relevant product standard
- ❑ Suitable for the purpose intended
- ❑ Securely fixed and suitably labelled
- ❑ Non-conductive finishes on switchgear removed at protective conductor connections and if necessary made good after connecting
- ❑ Correctly earthed
- ❑ Conditions likely to be encountered taken account of, that is suitable for the foreseen environment
- ❑ Correct IP rating applied
- ❑ Suitable as means of isolation, where applicable
- ❑ Not accessible to person normally using a bath or shower
- ❑ Need for isolation, mechanical maintenance, emergency and functional switching met
- ❑ All connections secure
- ❑ Cables correctly terminated and identified
- ❑ No sharp edges on cable entries, screw heads etc. which could cause damage to cables
- ❑ All covers and equipment in place and secure
- ❑ Adequate access and working space
- ❑ Enclosure suitable for mechanical protection and, where applicable, for fire protection
- ❑ Protection against direct contact
- ❑ Correct connection of equipment
- ❑ Choice and setting of protective devices (protection against overcurrent)
- ❑ Protective device attributed individually for each circuit
- ❑ Wiring correctly fixed in distribution board

6. Luminaires

Lighting points

- ❑ Correctly terminated in a suitable accessory or fitting
- ❑ Not more than one flex unless designed for multiple pendants
- ❑ Flexible support devices used
- ❑ Switch wires identified
- ❑ Holes in ceiling above rose made good to prevent the spread of fire
- ❑ Suitable for the mass suspended
- ❑ Suitably located
- ❑ Emergency lighting

7. Heating

- ❑ Visible indication of compliance with the appropriate product standard
- ❑ Class 2 insulation or protective conductor connected

8. Protective Devices

- ❑ Visible indication of compliance with the appropriate product standard, where required in the relevant product standard
- ❑ RCDs provided where required
- ❑ Discrimination between RCDs considered

9. Other

C. Identification

Labelling

- ❑ Warning notices
- ❑ Danger notices
- ❑ Identification of conductors
- ❑ Isolation devices
- ❑ Switching devices
- ❑ Diagrams and schedules
- ❑ Protective devices

ANNEX SS
(*Clause* 6)
(*Normative*)

REPORT OF VERIFICATION

Table 65 Model Form for Circuit Details and Test Results Schedule

INFORMATION REGARDING DISTRIBUTION BOARD (1)				
Description:	Ref.:	Manufacturer		
Rated voltage, *Un*: V	Nominal current, I_n: A	Frequency: Hz	Protection IP degree:	Short-circuit withstand capability of distribution board, *I*cc kA

MAIN SUPPLY TO DISTRIBUTION BOARD (6)							
Protective device:	Type:	Rating, *In*: A	Short circuit capacity rating kA	RCD: mA	*I*cp: kA (2)	*Zs*: □	CSA supply condition Section: L= mm²; PE= mm²

CIRCUIT DETAILS										TEST RESULTS														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Circuit No.	Description room served	Number of points	Function	Connection load	Cables/Cond.		Circuit protection			Circuit characteristics			Insulation resistance				RCD				Touch voltage	Polarity test	PE continuity	Remarks+ national requirements
					Type	Section L/PE	I_n (A)		Type	Z_s	I_p (A)		Mπ				I_n	I_d	T_d					
			(5)	kW (9)		Mm²	Fuse	Circuit breaker		Ω	L-N	L-PE	N-PE	L1-PE	L2-PE	L3-PE	A	mA	(3) (4)	(7)	(8)	(3)		

NOTES

1 By enquiry (manufacturer, name plate or technical doc.)

2 By measurement or calculation

3 Enter C if complies or NC if does not comply

4 Complete test where appropriate shall be performed including touch voltage and tripping time at rated current

5 Enter appropriate function code (see opposite)

6 Only to be completed if the distribution board is not connected directly to the origin of the installation

7 Only required where supplementary equipotential bonding has been installed in accordance with 413.1.3.6

8 Record connected load where readily identifiable

Abbreviations

L	Line
T_d	Test trip time
Z_s	Fault loop impedance
CSA	Cross-sectional area
I_{cp}	Prospective short-circuit current at main busbars of distribution board r.m.s. value
I_p	Measured short-circuit current at end of consumer supply line. For socket outlets circuits, measurement shall be made at each S/O and to record only the worst case
I_{cw}	Short-circuit withstand of equipment

Function code (for column 4)

C	Cooking	W/H	Water heating
S/O	Socket outlet	S/H	Storage heaters
UFH	Under floor heating	Li	Lighting
H	Heating	HP	Heat pump

ANNEX TT

(*Clause* 6)

EXTRACTS FROM CENTRAL ELECTRICTTY AUTHORITY NOTIFICATION
New Delhi, the 20th September, 2010

No. CEVl/59/CEA/EL - In exercise of the powers conferred by section 177 of the Electricity Act, 2003 (36 of 2003); the Central Electricity Authority hereby makes the following regulations for Measures relating to Safety and Electric Supply, namely:-

Chapter I

1. Short title and Commencement—(1) These regulations may be called the Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2010

(2) They shall come into force on the date of their final publication in the Official Gazette.

Chapter II

3. Designating person(s) to operate and carry out the work on electrical lines and apparatus — (1) A supplier or a consumer, or the owner, agent or manager of mine, or the agent of any company operating in an oil field or the owner of a drilled well in an oil field or a contractor who has entered into a contract with a supplier or a. consumer to carry out duties incidental to the generation, transformation, transmission, conversion, distribution or use of electricity shall designate persons for the purpose to operate and carry out the work on electrical lines and apparatus.

(2) The supplier or consumer, or the owner, agent or manager of a mine, or the agent of any company operating in an oil-field or the owner of a drilled well in an oil field or a contractor referred to on sub-regulation (1) shall maintain a register wherein the names of the designated persons and the purpose for which they are engaged, shall be entered.

(3) No person shall be designated under sub-regulation (l) unless,—

(i) he possesses a certificate of competency or electrical work permit, issued by the Appropriate Government

(ii) his name is entered in the register referred to in sub regulation (2)

4. Inspection of designated officers and other safety measures—(1) The register maintained under sub-regulation (2) of regulation 3 shall be produced before the Electrical Inspector when required by him.

(2) If on inspection, the Electrical Inspector finds that the designated person does not fulfill the required qualification, he shall recommend the removal of the name of such persons from the register.

5. Electrical Safety Officer—(1) All suppliers of electricity including generating companies, transmission companies and distribution companies shall designate an Electrical Safety Officer for ensuring observance of safety measures specified under these regulations in their organisation for construction, operation and maintenance of power stations, sub-stations, transmission and distribution lines.

(2) The Electrical Safety Officer shall be an E1ectrical Engineering degree holder with at least ten years of experience in operation and maintenance of electricity plants or an Electrical Engineering Diploma holder with at least fifteen years of experience in operation and maintenance of electric plant.

(3) The Electrical Safety Officer designated under sub-regulation (1) shall ensure periodic inspection of such installations, get them tested and keep a record thereof and such records shall be made available to the Electrical Inspector if and when required.

Chapter III
General safety requirements

12. General safety requirements, pertaining to construction, installation, protection, operation and maintenance of electric supply lines apparatus—(1) All electric supply lines and apparatus shall be of sufficient rating for power, insulation and estimated fault current and of sufficient mechanical strength, for the duty cycle which they may be required to perform under the environmental conditions of installation, and shall be constructed, installed, protected, worked and maintained in such a manner as to ensure safety of human beings, animals and property.

(2) Save as otherwise provided in these regulations, the relevant code of practice of the Bureau of Indian Standards or National Electrical Code, if any, may be followed to carry out the purposes of this regulation and in the event of any inconsistency, the provisions of these regulations shall prevail.

(3) The material and apparatus used shall conform to the relevant specifications of the Bureau of Indian Standards or International Electro-Technical Commission where such specifications have already been laid down.

(4) All electrical equipment shall be installed above

the Mean Sea level (MSL) as declared by local Municipal Authorities and where such equipment is to be installed in the basement, consumer shall ensure that the design of the basement should be such that there is no seepage or leakage or logging of water in the basement.

13. Service lines and apparatus on consumer's premises—(1) The supplier shall ensure that all electric supply lines, wires, Fittings and apparatus belonging to him or under his control, which are on a consumer's premises, are in a safe-condition and in all respects fit for supplying electricity and the supplier shall take precautions to avoid danger arising on such premises from such supply lines, wires, fittings and apparatus.

(2) Service lines placed by the supplier on the premises of a consumer which are underground or which are accessible shall be so insulated and protected by the supplier as to be secured under all ordinary conditions against electrical, mechanical, chemical or other injury to the insulation.

(3) The consumer shall, as far as circumstances permit, take precautions for the safe custody of the equipment on his premises belonging to the supplier.

(4) The consumer shall also ensure that the installation under his control is, maintained in a safe condition.

14. Switchgear on consumer's premises—(1) The supplier shall provide a suitable switchgear in each conductor of every service line other than an earthed or earthed neutral conductor or the earthed external conductor of a concentric cable within a consumer's premises, in an accessible position and such switchgear shall be contained within an adequately enclosed fireproof receptacle:

Provided that where more than one consumer is supplied through a common service line, each such consumer shall be provided with an independent switchgear at the point of rigid junction to the common service.

(2) Every electric supply line other than the earthed or earthed neutral conductor of any system or the earthed external conductor of a concentric cable shall be protected by suitable switchgear by its owner.

15. Identification of earthed and earthed neutral conductors and position of switches and switchgear therein—Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, the following conditions shall be complied with:

(i) an indication of a permanent nature shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected thereto, to enable such conductor to be distinguished from any live conductor and such indication shall be provided-

(a) where the earthed or earthed neutral conductor is the property of the supplier, at or near the point of commencement of supply;

(b) where a conductor forming part of a consumer's system is to be connected to the supplier's earthed or earthed neutral conductor, at the point where such connection is to be made;

(c) in all other cases, at a point corresponding to the point of commencement of supply or at such other points as may be approved by an Electrical Inspector.

(ii) no cut-out, link or switch other than a linked-switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two wire-system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto.

Provided that the above requirement shall not apply in case of-

(a) a link for testing purposes, or

(b) a switch for use in controlling a generator or transformer

16. Earthed terminal on consumer's premises—(1) The supplier shall provide and maintain on the consumer's premises for the consumer's use, a suitable earthed terminal in an accessible position at or near the point of commencement of supply.

Provided that in the case of installation of voltage exceeding 250V the consumer shall, in addition to the aforementioned earthing arrangement, provide his own earthing system with an independent electrode.

Provided further that the supplier may not provide any earthed terminal in the case of installations already connected to his system on or before the date to be specified by the State Government in this behalf if he is satisfied that the consumer's earthing arrangement is efficient.

(2) The-consumer shall take all reasonable precautions to prevent mechanical damage to the earthed terminal and its lead belonging to the supplier.

(3) The supplier may, recover from the consumer the cost of installation on the basis of schedule of charges

published by him in advance and where such schedule of charges is not published, the procedure laid down, in regulation 63 shall apply.

Explanation—For the purposes of sub-regulation (1), the expression "point of commencement of supply of electricity" shall mean the point at the incoming terminal of the switchgear installed by the consumer.

17. Accessibility of bare conductors—Where bare conductors are used in a building, the owner of such conductors shall,—

(a) ensure that they are inaccessible;

(b) provide in readily accessible position switches for rendering them dead whenever necessary; and

(c) take such other safety measures as are specified in the relevant Indian Standards.

Chapter V

Safety Provisions for Electrical Installations and Apparatus of Voltage not Exceeding 650 Volts

40. Test for resistance of insulation—(1) Where any electric supply line for use at voltages not exceeding 650 V has been disconnected from a system for the purpose of addition, alteration or repair, such electric supply line shall not be reconnected to the system until the supplier or the owner has applied the test prescribed under regulation 33.

(2) The provision under sub-regulation (1) shall not apply to overhead lines except overhead insulated cables, unless the Electrical Inspector otherwise directs in any particular case.

41. Connection with earth—The following conditions shall apply to the connection with earth of systems at voltage normally exceeding 125 V but not exceeding 650 V, namely:

(i) neutral conductor of a 3-phase, 4-wire system and the middle conductor of a 2-phase, 3-wire system shall be earthed by not less than two separate and distinct connections with a minimum of two different earth electrodes or such large number as may be necessary to bring the earth resistance to a satisfactory value both at the generating station and at the sub-station.

(ii) the earth electrodes so provided, shall be inter-connected to reduce earth resistance.

(iii) neutral conductor shall also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

(iv) in the case of a system comprising electric supply lines having concentric cables, the external conductor of such cables, shall be earthed by two separate and distinct connections with earth.

(v) the connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating fault.

(vi) in a direct current three wire system, the middle conductor shall be earthed at the generating station only and the current from the middle conductor to earth shall be continuously recorded by means of a recording ammeter, and if at any time the current exceeds one-thousandth part of the maximum supply current, immediate steps shall be taken to improve the insulation of the system.

(vii) where the middle conductor is earthed by means of a circuit breaker with a resistance connected in parallel, the resistance shall not exceed ten ohms and on the opening of the circuit breaker, immediate steps shall be taken to improve the insulation of the system, and the circuit breaker shall be re-closed as soon as possible.

(viii) the resistance shall be used only as a protection for the ammeter in case of earths on the system and until such earths are removed and immediate steps shall be taken to locate and remove the earth.

(ix) in the case of an alternating current system, there shall not be inserted in the, connection with earth any impedance, other than that required solely for the operation of switchgear or instruments, cut-out or circuit breaker, and the result of any test made to ascertain whether the current, if any, passing through the connection with earth is normal, shall be duly recorded by the supplier.

(x) no person shall make connection with earth by the aid of, nor shall he keep it in contact with, any water mains not belonging to him except with the consent of the owner thereof and ofthe Electrical Inspector.

(xi) alternating current systems which are connected with earth as aforesaid shall be electrically interconnected:

Provided that each connection with earth is bonded to the metal sheathing and metallic armouring, if any, of the electric supply lines concerned.

(xii) the frame of every generator, stationary motor, portable motor, and the metallic parts, not intended as conductors, of all transformers and any other apparatus used

for regulating or controlling electricity, and all electricity consuming apparatus, of voltage exceeding 250 V but not exceeding 650 V shall be earthed by the owner by two separate and distinct connections with earth.

(xiii) neutral point of every generator and transformer shall be earthed by connecting it to the earthing system by not less than two separate and distinct connections.

(xiv) all metal casing or metallic coverings containing or protecting any electric supply line or apparatus shall be connected with earth and shall be so joined and connected across all junction boxes and other openings as to make good mechanical and electrical connection throughout their whole length:

Provided that conditions mentioned in this regulation shall not apply, where the supply voltage does not exceed 250 V and the apparatus consists of wall tubes or brackets, electroliers, switches, ceiling fans or other fittings,, other than portable hand lamps and portable and transportable apparatus, unless provided with earth terminal and to class-II apparatus and appliances:

Provided further that where the supply voltage is not exceeding 250 V and where the installations are either new or renovated, all plug sockets shall be of the three pin type, and the third pin shall be permanently and efficiently earthed.

(xv) All earthing systems shall, -

a) consist of equipotential bonding conductors capable of carrying the prospective earth fault current and a group of pipes, rods and plate electrodes for dissipating the current to the general mass of earth without exceeding the allowable temperature limits as per relevant Indian Standards in order to maintain all non-current carrying metal works reasonably at earth potential and to avoid dangerous contact potentials being developed on such metal works;

b) limit earth resistance sufficiently low to permit adequate fault current for the operation of protective devices in time and to reduce neutral shifting;

c) be mechanically strong, withstand corrosion and retain electrical continuity during the life of the installation and all earthing systems shall be tested to ensure efficient earthing, before the electric supply lines or apparatus are energised.

(xvi) all earthing systems belonging to the supplier shall in addition, be tested for resistance on dry day during the dry season not less than once every two years.

(xvii) a record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Electrical Inspector when required.

Explanation—The expression “Class-II apparatus and appliance” shall have the same meaning as is assigned to it in the relevant Indian Standards.

42. Earth leakage protective device—The supply of electricity to every electrical installation other than voltage not exceeding 250 V below 5 kW and those installations of voltage not exceeding 250V which do not attract provisions of section 54 of the Act, shall be controlled by an earth leakage protective device so as to disconnect the supply instantly on the occurrence of earth fault or leakage of current:

Provided that such earth leakage protective device shall not be required for overhead supply lines having protective devices which are effectively bonded to the neutral of supply transformers and conforming to regulation 73.

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BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones : 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.org.in

Regional Offices:			*Telephones*
Central	:	Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	2323 7617 2323 3841
Eastern	:	1/14 C.I.T. Scheme VII M, V. I. P. Road, Kankurgachi KOLKATA 700054	2337 8499, 2337 8561 2337 8626, 2337 9120
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